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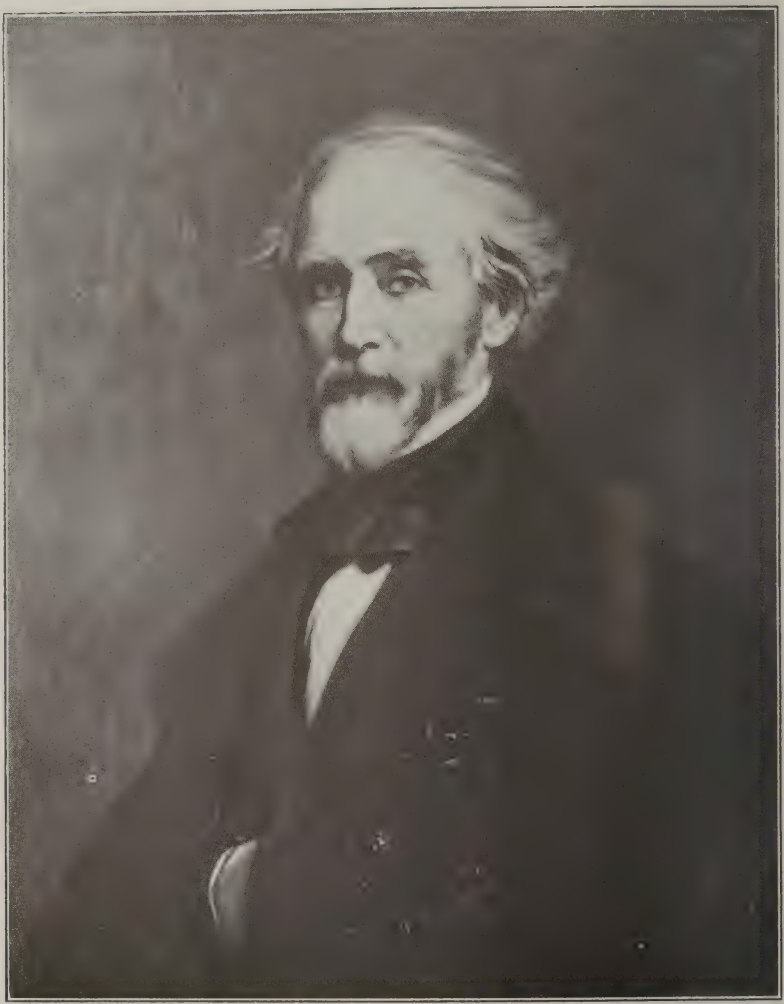

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Born April 2, 1802.

Cadet, U. S. M. A., 1820–1824.
Second Lieutenant, Corps of Engineers, 1824–1832.
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Died, 1871.

Breakwater and Jetty Construction in the New London, Conn., District.

BY

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Assistant Engineer.

The location, character and dimensions of works of this class depend, of course, upon the geographical and physical characteristics of the coast line and harbors, and upon the character and extent of the commerce.

This district includes the rivers and harbors in Connecticut, the Pawcatuck River (between Connecticut and Rhode Island), and the Connecticut River in Connecticut and Massachusetts. It follows that the entrances to all waterways in this district are along the northerly shores of Long Island Sound and Fishers Island Sound. These two sounds are geographically one body of water, about 100 statute miles long, from Execution Rocks, at the westerly end, to Stonington, at the easterly end; about 2 miles wide at either end, but gradually increasing in width to about 19 miles midway. The major axis passes very nearly through the above-named points at either end, and its azimuth, referred to true meridian, is about 72 degrees. The depth, except near the shores and within 10 miles of either end, ranges from 10 to 30 fathoms, but only comparatively small areas are as deep as 20 fathoms.

The northern shore is in general irregular with many promontories, bays, islands and inlets. Three large rivers, the Connecticut, Housatonic and Thames, and numerous smaller streams, many of them navigable to a greater or less extent, have their outlets along this shore. The greater part of the Connecticut coast is rocky, much of it granite formation, and there are considerable stretches of sand beach. The southern, or Long Island, shore from the westerly end of the Sound to Port Jefferson, about 35 miles, affords several excellent harbors; but from Port Jefferson to Plum Gut, about 45 miles, hills of glacial drift form an unbroken coast line

except for one small harbor, Mattituck Inlet, which affords shelter only for craft drawing less than 7 feet. It follows from the above that there is very little commerce along this shore.

Very heavy seas, such as occur in the ocean, are, of course, impossible in the waters of this district. Storms, instead of producing long, heavy seas, as would be the case in a much larger and deeper body of water, very rapidly "kick up" a nasty choppy sea that is very dangerous for many of the vessels navigating these waters. The worst storms for the Connecticut shore are from the southeasterly quadrant, but southwesterly gales often do much damage. Winds from the two northerly quadrants often force a vessel to seek refuge under the lee of the Connecticut shore or in its harbors, but rarely cause much damage along this shore.

The commerce of Long Island Sound is very large and consists of two distinct classes: (1) vessels plying between New York and other ports not located on the Sound, and which merely pass through the Sound for convenience; and (2) vessels bound to and from ports located along the Sound or on its tributary rivers.

The first-named class consists of seagoing vessels to which the Sound itself is a fairly sheltered harbor, and consequently no provision for their safety in the way of harbors is necessary in this district.

The second class is much more numerous and much less seaworthy than the first. It may be subdivided as follows: (*a*) large seaworthy vessels, such as tramp steamers and deep-water sailing craft bound from distant ports to ports along the Sound, or, though much more rarely, vice versa. This class is not very numerous and enters only the larger harbors. (*b*) Passenger and freight steamers running on schedule between different Sound ports and between such ports and New York. This class comprises about 15 different lines, operating about 25 vessels ranging from 100 to nearly 2,000 tons net register. (*c*) Coasting schooners plying between Sound ports and between such ports and other ports nearby, as New York, Providence, etc. This class is quite numerous and carries much of the heavy bulk freight except coal, which these vessels do not handle extensively. Vessels of this class probably average about 200 tons net register. (*d*) Coal barges and scows in tow. These vessels carry much the greater portion of this class of freight and constitute a very large part, probably about 50 per cent, of the total commerce. They are mostly straight-sided, square-ended scows, averaging in capacity about 1,000 tons, and drawing

about 12 feet, with very little freeboard. They are made up into tows of from two or three to a dozen or more and are towed by one or more tugs. (*e*) Steam canal boats and lighters carrying from 200 to 500 tons of freight such as sand, clay, cement, iron, etc. This is not a very numerous class. (*f*) Oyster boats. These are engaged in the cultivation of oysters in Long Island Sound. This is a very important industry in these waters and employs 100 or more of these vessels, ranging from 10 to 340 tons (very few over 100 tons) net register. The larger vessels are steamers and the smaller ones gasoline boats. (*g*) The mosquito fleet, comprising a very large number of small pleasure craft, power and sail, fishermen, lobstermen, etc.

Of the above-described vessels, those under (*a*) can safely ride out any storm in Long Island Sound. Their only requirement is sufficient depth to enable them to enter the large harbors and discharge or load cargo. Their number is so small that they have been a controlling factor in only a few of the projects for the larger harbors, such as New London, New Haven and Bridgeport harbors.

The vessels under (*b*) are sufficiently seaworthy to be obliged but rarely to seek shelter after once starting a trip. If the weather is particularly bad they may not leave their wharves. This class is not a controlling factor in the projects for improvement, except as regards depth of channel, and in many cases the draft of such vessels, which rarely exceeds 12 feet, is less than that of the other classes which must be provided for.

The coasters (*c*) are fairly seaworthy under favorable conditions, but their progress is slow; they are often undermanned and very heavily laden, frequently with large deck-loads, and if caught in a severe storm with no good shelter, are in great danger. Wrecks and loss of life occur with this class nearly every year.

The barge tows (*d*) are the class that need the greatest protection. Their progress is very slow, rarely over 4 miles per hour, often much less. The towing is almost always done with the tide, as the tows can usually make little or no progress against it. The construction of the vessels is such, and they are so deeply laden, that they are very unseaworthy.

The two classes last named really determine the need for protective works in this district. Harbors that will provide shelter for them will afford ample shelter for the three remaining classes,

which are faster and hence are not so likely to be caught in a storm without shelter.

Although Long Island is comparatively small, it is noted among boatmen for its sudden changes of weather, and the quickness with which a dangerous sea comes up, often in two or three hours. It thus becomes necessary to afford harbors of refuge at frequent intervals, and experience has shown that these harbors should not be more than 20 miles apart, and even then numbers of vessels, particularly coal barges, are lost each year.

Breakwaters and jetties in this district may be roughly divided into those designed for protection and those intended primarily to improve the waterway by controlling the currents or preventing erosion of the banks. The first class, or breakwaters proper, are usually located at or just outside of the entrance to a harbor, where they are usually exposed to severe storms, and must be so built as to withstand the resulting seas. They may be constructed solely for the purpose of forming a harbor of refuge where no natural harbor of consequence exists, as at Duck Island (Fig. 14); they may serve to increase the size and usefulness of a natural harbor, as at Stonington and New Haven (Fig. 13); or they may serve a two-fold purpose by protecting a harbor from filling as the result of wave action, and at the same time forming a shelter for vessels, as at Bridgeport and Black Rock harbors (Fig. 15).

Structures of the second class, jetties and dikes, are often so situated within harbors and rivers that they are not subject to wave attack, and hence may be of much lighter construction than those of the first class. In some cases, however, as at the mouth of a river, they not only control the current, but also protect the entrance channel from wave action, and in such cases their construction must be similar to a regular breakwater. The Sandy Point dike in New Haven Harbor (see Fig. 13), the Stratford dike in the Housatonic River, and the dikes in the Connecticut and Thames rivers are examples of controlling works, while the dikes at the mouth of the Connecticut River (Fig. 14) furnish an excellent example of works which both protect the channel and control and direct the current.

In the early history of the district various forms of construction were used. One of the first two breakwaters built by the United States in this district was begun in 1829, for the protection of Southport Harbor. (See Fig. 1.) It was 1,320 feet long, 14 feet wide on bottom, 8 feet wide on top, 8½ feet high

Fig. 1. Southport Breakwater. Looking northerly from outer end. October 21, 1914. Top width, 5 feet.

Fig. 2. Stonington Inner Breakwater. Looking westerly. August 3, 1914. Top width, 12 feet.

above "common low water," and was built of schistose gneiss from a nearby quarry. The sides were long, irregular pieces of stone laid as headers, and the top was of similar pieces extending clear across it; the interior was filled with smaller stone. This work was apparently completed, or very nearly so, in 1830, but repairs were necessary from time to time, and in 1875-1876 a course of roughly squared granite capstones 5 feet long and 2 feet thick, laid as headers, with 3-inch joints, was added, the original work having been "badly shattered on top by the action of the sea." This breakwater has been successful in protecting the entrance to the harbor from the action of southeasterly storms, but the type of construction is poor. The stones used for the original work are too small, few of them weighing half a ton and many less than 500 pounds each; the sides are too steep, and the bottom width is not sufficient for permanence. The depth in front of it is so slight, less than 2 feet at low tide, that any very heavy seas are broken, otherwise the entire structure would last but a short time. As it is, repairs are frequently needed.

At the same time that the breakwater was built, a dike 1,350 feet long was constructed along the easterly side of the harbor, practically forming a northerly extension of the breakwater. It was 5 feet wide on top with sides of marsh sod, laid with a slope of 1 on 1, and the interior composed of alternate thin layers of brush and mud. Where the bottom was soft a foundation of fascines was used. Subsequently, the westerly or harbor side was revetted with stone. Repairs have been made from time to time, but none in recent years, and the dike still serves its purpose and prevents material from the bank from washing into the channel.

The other breakwater (Fig. 2) was begun in 1828, completed in 1833, for the protection of Stonington Harbor, and was of quite different construction. The lower portion, up to about low water level, was of riprap and the upper portion was composed of seven courses of roughly rectangular slabs of granite, each course about a foot thick, the top course composed of headers and the others of headers and stretchers. The courses were laid so as to form a series of steps on the outer side, having a general slope of about 1 on 3, while the slope on the inner or harbor side was about 4 on 1. The top width was 12 feet, height 8½ feet above mean low water, and the total length 740 feet. A total of 82,268 tons of stone was used in the construction, and the entire cost was between \$36,000 and \$37,000. This breakwater is still standing,

Fig. 3. Fayerweather Island Breakwater. Looking northerly. October 21, 1914. Top width, 9 to 10 feet.

Fig. 4. Fayerweather Island Breakwater, Showing Outer Slope. October 21, 1914. Note where material has been cut away in places in front of the toe.

but as two other breakwaters have been since built outside, its usefulness has largely disappeared. The type of construction is not a good one; it is unduly expensive, and the character of the front slope is such that it is very readily injured by wave action. The stones used in this particular case were few of them over 1 ton in weight and many of them considerably smaller; larger stones should have been used for permanence in this type of construction.

In 1836 a breakwater (Figs. 3 and 4) was begun to close a breach between the northern and southern portions of Fayerweather Island, and to protect the southerly portion of the island from erosion. This island forms the easterly side of Black Rock Harbor, and the breakwater was essential for the preservation of the harbor (see Fig. 15). It was entirely different in construction from either of those just described, the outside being composed of flat slabs of stone laid like a pavement and the interior of small stone, mainly cobbles, beach and field stone. The top was flat, about 8 feet wide, and averaging about 14½ feet above mean low water. The side slopes varied greatly in different portions of the breakwater, the outer slope ranging from about 1 on 2 to 1 on 3, and the inner slope from about 1 on 1 to 1 on 2. The toe, where it met the beach, was secured by long pieces of stone set on edge and extending down into the beach several feet. The total length of the structure as originally constructed was somewhat less than 2,000 feet, and the original cost is stated to have been $21,550. This form of construction, while presenting a very good appearance when the structure is new, is very unsatisfactory when it becomes necessary to make repairs. The smooth surface of the sides allows waves to run up on them much farther than would be the case with a rough surface, and the back-wash tends to cut away from the foot. If this cutting proceeds far enough so as to undermine the toe, as has happened in several places in the structure under consideration, the resulting damage is very difficult to repair because the entire side tends to slip down, the small rounded stones beneath acting almost like rollers. In the case of this structure it has been necessary to protect it by riprap and small groins, and in some places the slopes were in such poor condition that they were covered with riprap, as the easiest form of repair. The breakwater has served its purpose so far as the protection of the harbor is concerned, and at present is in fairly good conditon.

The first riprap structure to be built in this district was begun in 1871, for the protection of Bridgeport Harbor, by arresting the

movement of sand drift from the eastward. As originally begun, it was a jetty rather than a breakwater, and was extended southwesterly from the east shore of the harbor. It was first built to a triangular cross section, with side slopes of 1 on 1 and top at a height of about 2 feet above high water of spring tides. The specifications for this work provided that it be "of riprap granite, in blocks averaging not less than 1½ tons each, and none weighing less than one-fourth of a ton" and that they be "as nearly cubical as practicable, the smallest dimension not less than one-third of the greatest." The price paid for the first work was $2.84 per long ton, and in about two years the structure has been extended 1,380 feet. In 1900, and again in 1907-1908, the structure was increased in cross section and extended much farther to the southwestward, to form the present easterly breakwater for the protection of the harbor. (Plate II.)

Since the construction of the Bridgeport breakwater described above, only riprap has been used in this district for the construction of works exposed to wave attack. In some of the dikes and jetties inside harbors and in rivers, where not exposed to storms, a different form of construction has been used. An example of these is the Sandy Point dike in New Haven Harbor, which was begun in 1883, in order to concentrate the current across the Fort Hale bar (see Fig. 13). The portion of this structure first built consisted of two rows of creosoted piles, 8 feet apart, waled, and fastened together with wooden cross ties and iron rods, and filled with small riprap stone. The portion built subsequently to 1886 was of riprap. This form of pile and stone dike is quite often used, and in places is quite successful. For a description of this particular structure, with especial reference to the durability of the piling, see PROFESSIONAL MEMOIRS, Vol. 1, page 219. [Fig. 14 herewith is reproduced from that article.] In the Connecticut River several different forms of dikes have been used. The Hartford dike, built to control the current across the Hartford bar, is largely composed of roughly rectangular blocks of sandstone, weighing several tons each, laid with a nearly vertical face on the channel side, and backed with sandstone riprap. Similar blocks of sandstone have been used for the tops of other dikes along this river. At several points in the river spur dikes, for contraction purposes or to protect the bank, have been built, and these have sometimes been constructed of double lines of piles, similar to the

New Haven dike described above, but filled with brush weighted down with stone; brush fascines with a small amount of riprap to hold them in place have also been used in connection with the spur dikes.

The advantages of riprap in this district are that it is cheap; that its rough surface serves to break up the seas, while at the same time the structure itself is very strong; that it is not readily damaged by storms; and that if damage does occur, repairs are very easily and cheaply made by simply adding new stone.

As stated in the early part of this article, the Connecticut shore

Fig. 5. East Breakwater, New Haven Harbor. Looking easterly from Southwest Ledge Light. October 22, 1914. A typical example of breakwater built entirely of riprap with slightly rounded top, 12 feet wide.

of Long Island Sound is largely of granite, and within the limits of this district there are at least six quarries which furnish an excellent quality of granite or firm, granitoid gneiss, suitable for riprap for breakwater construction. These quarries are so located that their output may be readily handled by a vessel directly from the quarry to the site of the work and consequently the cost is low. Where stone has been purchased at the quarry the prices have ranged from 60 to 75 cents per ton delivered on board. However, com-

paratively little stone has been purchased in this way, and only when it was to be placed by plant owned by the United States. Usually work of this character is done by contract and the price is for the stone delivered in place in the structure. In such cases the prices ordinarily range from about $1 to $1.50, depending upon the length of haul, the size of the job, the depth of water at the site of the work, and various other factors. Such work has been done as low as 79 cents per long ton, and on the other hand, has sometimes exceeded $2.00; but these extremes are rarely reached.

Fig. 6. West Breakwater, New Haven Harbor. Looking westerly, during progress of work, October 22, 1914. This breakwater is built of riprap with top, 12 feet wide, of heavy capstones.

The minimum was reached for work done by a concern, now out of business, which, it is understood, lost money on the job, and the price will probably never again be duplicated in this district. The maximum is reached in cases where the water is shoal and there is difficulty in delivery.

At Portland, on the Connecticut River, there are large brownstone (Connecticut River sandstone) quarries, some of which have been in operation for about 100 years. Stone from these quarries

has been used in various structures in this district. Such stone is generally cheaper than granite, but is not as desirable for most purposes. When subjected to alternate thawing and freezing, as constantly takes place during the winter in tidal waters, it deteriorates quite rapidly. As quarried, it comes out in roughly rectangular blocks, which, while excellent for capstones or for some other purposes, where a comparatively smooth surface is desired, is not desirable for riprap work, as such blocks do not fit in together as angular stones do, and are apt to build into "cob houses" which subsequently result in settlement. For these reasons the use of such stone has been discontinued, in recent years, for works in Long

Fig. 7. East Breakwater, Bridgeport Harbor. Looking northerly from outer end. October 16, 1914. A good example of the all-riprap type of breakwater.

Island Sound, but it has been used successfully along the Connecticut River, where the tidal range is small.

The earlier projects for riprap breakwaters in this district provided for larger cross sections and flatter slopes than later experience indicates are necessary. The project for the New Haven breakwaters originally provided for a height of 6 feet above mean high water, top width of 12 feet, outer slope 1 on 2 and inner slope 1 on 1; but in 1910 the project was revised so as to provide for an outer slope of 1 on 1½. Experience has shown that a top width of

not over 10 feet would doubtless have answered every purpose. The Duck Island breakwaters are 9 feet high above mean low water, 8 feet wide on top, outer slope 1 on 1½, and inner slope 1 on 1, and nothing approaching failure has ever occurred. In fact, the only cases of breaches occurring in any breakwater in the district have been where they were temporarily built to very much smaller cross section than called for by the project. In some such cases, where the structures were left for a number of years, small breaches, down to about low water level, have occurred, but such damage is always very readily repaired by adding new stone.

Two different types of riprap breakwaters have been constructed

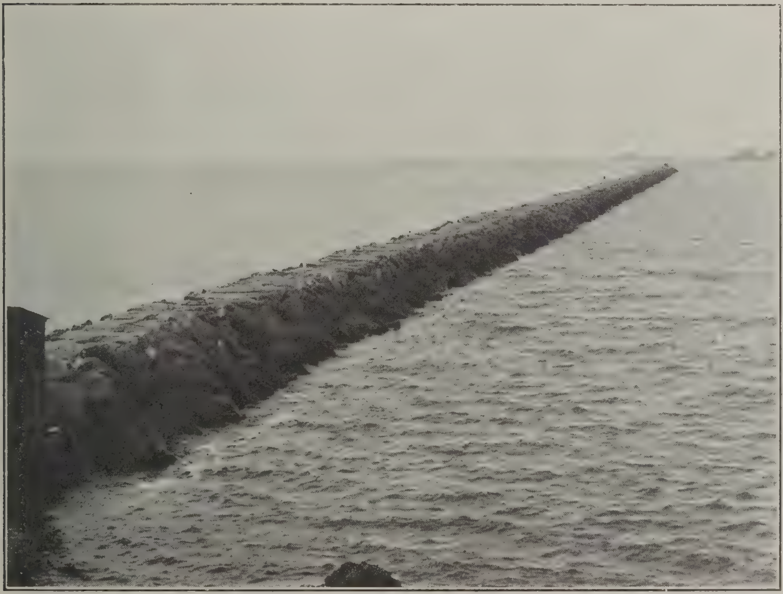


Fig. 8. Duck Island Harbor of Refuge. Looking westerly from Duck Island toward Kelsey Point, westerly breakwater in foreground and Kelsey Point breakwater showing on horizon. November 10, 1914. The tops of the breakwaters are 8 feet wide and are 9 feet above mean low water.

in the district. The first type (Figs. 5 and 7) consists entirely of riprap with a slightly rounded top; the second type (Figs. 6, 8 and 10) has a flat top composed of roughly rectangular capstones and the remainder of the work riprap. Structures of the latter type present a rather better appearance and the top stones are not so likely to be displaced, but it is somewhat questionable whether the advantages justify the increased cost. In the case of the larger breakwaters, built in deep water, as at New Haven and Duck Island,

the contractors have been permitted to use "quarry run" stone below a plane 12 feet below mean low water. Such stone is usually brought in ordinary bottom-dumping scows carrying from 500 to 1,000 tons, and dumped in the same manner that mud or similar material is dumped. The stones in the portion of the breakwater above a plane 12 feet below mean low water is required to be placed one stone at a time, by means of derricks. (See Figs. 9 and 12.) It must be in pieces weighing not less than 1 ton each, and averaging at least 2 tons each, except that in some cases the use of stone down to half a ton is allowed for filling in the interstices between

Fig. 9. Work in Progress on West Jetty at Mouth of Connecticut River. April 17, 1914. Capacity of vessel, 225 long tons.

the large stones, and a small amount of "quarry chip," ranging in size from 5 to 100 pounds, has been allowed for bedding the capstones, with the proviso that the chip must not be used so as to prevent the capstones from resting directly on the large stones beneath, but simply to even up the bed. Where capstones have been used they have been required to be roughly rectangular in shape, weighing not less than 4 tons each, and with the least dimension not less than 3 feet; where the breakwater has a top width of 8 feet or more, it is required that the capstones be of such size that not more than two of them will be required to make the full width

of the breakwater; where the breakwater is not over 6 feet wide, generally only one stone is used to make the full width (Fig. 10). Although the specifications usually provide that stones for the body of the work be of the sizes named above, in actual practice the stones generally run considerably larger, and in the case of the New Haven breakwaters stones weighing 10 or 12 tons have been used. The use of a limited amount of quite small stones, down to even 500 pounds, is frequently desirable in order to chink in between the larger stones and make a more compact structure. If

Fig. 10. West Jetty at Mouth of Connecticut River. Looking northerly from the light at the outer end of breakwater. August 27, 1914. A good example of jetty with top of single row of large capstones. The top is 6 feet wide.

motion takes place among the large stones, the small ones drop down and wedge the large stones in place. Of course, along the ocean coasts or in places where a breakwater is likely to be exposed to very heavy seas, breakwaters such as described above would not be at all suitable, but in Long Island Sound they have proved entirely successful.

Ordinarily, no provision has been made for the prevention of scour ahead of the work, but in some places where the structure

has been at right angles, or nearly so, to a strong current, a blanket of small stone, about 2 feet thick, has been first placed to prevent the bottom from scouring in front of the work as it advances.

With the exception of a small amount of repair work, and the construction of a small breakwater northerly from Duck Island, all breakwaters and most of the dikes in the district have been built under contract. The various contractors have employed different kinds of plant. One of the largest concerns, which owned its own quarry, had a large fleet of derrick barges and bottom-dumping scows. Two kinds of derrick barges were used, one similar

Fig. 11. Clay Banks Training Dike, on the Connecticut River. Looking northerly, during progress of construction. August 27, 1914. A good illustration of the comparatively light form of construction used in river works where not exposed to wave action. Top width, 3 feet.

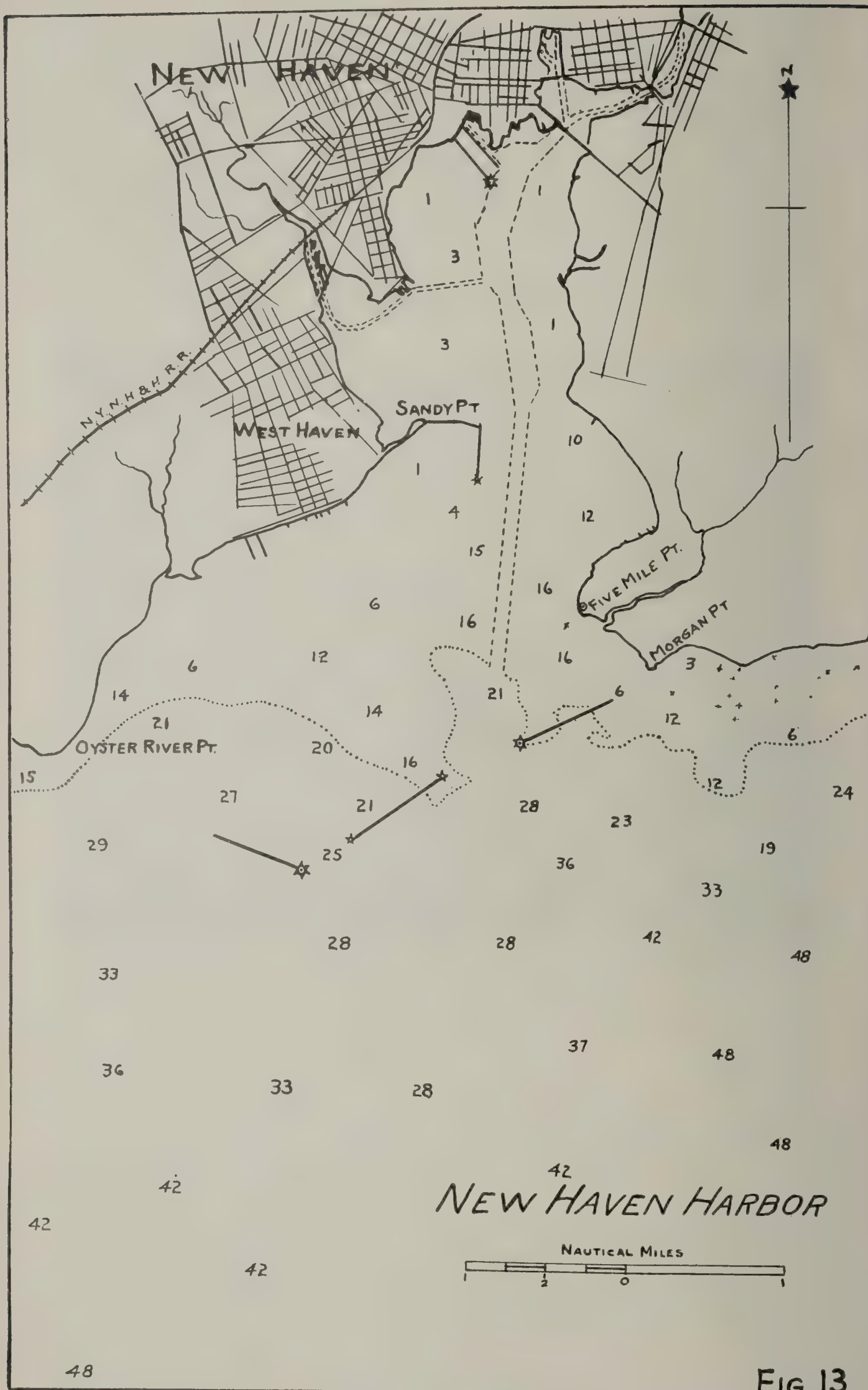
to the ordinary type with a mast and boom operated by a steam engine at one end of the lighter; and the other with two such derricks, one at each end (Fig. 12). The first, or single-derrick barge, ordinarily carried about 400 tons of stone, while the double-derrick barges carried up to about 1,000 tons. The bottom-dumping scows were ordinary mud scows, reinforced, and with pockets double sheathed inside for this work. None of these vessels was self-propelled, all of them being towed by powerful tugs. With

this plant over 42,000 tons of stone has been placed in a breakwater in a single month. Another successful plant is composed of one or more steam lighters, carrying 250 tons or so each, and towing one or more additional lighters fitted with derricks, but without propelling machinery. This plant is economical to operate and has done very successful work. Still another contractor utilizes schooners carrying from 200 to 250 tons each (Fig. 9). Ordinarily, the mainmast is removed and the foremast fitted with a long boom operated by a hoisting engine for handling the stone, the vessels being towed; but in the case of some small jobs the vessels have

Fig. 12. Double Derrick Barge Used in Construction of West Breakwater, New Haven Harbor, in 1909. Capacity of barge, fully loaded, about 800 tons.

been employed as sailing craft, thus doing away with the expense of a tug.

The inspection of work of this character requires very careful attention and the success of the work depends largely on having a good inspector. In some cases it is desirable to have an inspector both at the quarry and at the breakwater, but ordinarily this is not necessary after the vessels have been weighed in. In this district the weighing in is always done by employees of this office, and too much care can not be taken in this matter. In the first place, it is



NEW HAVEN HARBOR

FIG. 13.

very desirable that the vessel be fitted with interior glass tubes and wooden or metal strips carefully graduated into feet, tenths and hundredths for gauges, rather than to depend on outside marks on the vessel. It is usually difficult to read outside marks accurately, and they are always likely to be more or less defaced. The use of gauge glasses is much more satisfactory and has been required in

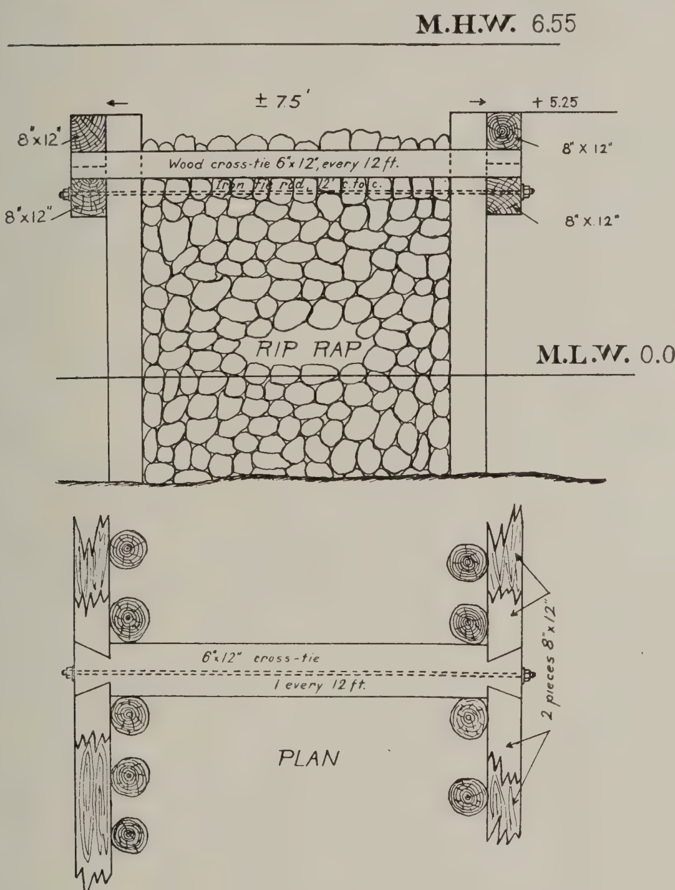


Fig. 14. Sandy Point Dike, New Haven Harbor.

most of the work recently done. Of course, the precaution should be taken to carefully tie up the marked scales, so that they can not be tampered with or moved without the knowledge of the inspector.

In the case of flat-bottomed vessels, scows and barges, six gauges are used, one in each corner and two amidships; but in the case of molded vessels, such as schooners, only three are required—at the

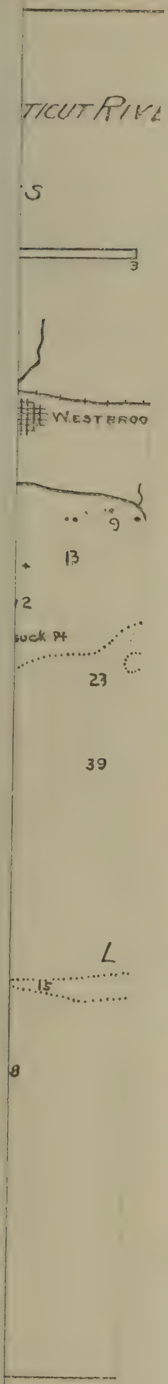
bow, stern, and amidships. During the process of the weighing in, care should be taken to distribute the load as evenly as possible in the vessel to keep her in approximately the same trim and to prevent warping and bending. In the case of large, flat-bottomed vessels, such as the double-derrick barges described above, considerable warping will take place, even with the greatest care, and this necessarily interferes with the correctness of the results. Less trouble is ordinarily experienced with vessels which have a good keel, but even these are likely to sag in the middle or at the ends if care is not used in loading.

Ordinarily, it has been found desirable to have one inspector constantly on the vessel to look after the loading while another attends to the weighing at the scales.

The center line of the breakwater is usually established by a transit line, and as the breakwater progresses stations are added from time to time. At the same time a careful line of levels is carried along the top with bench marks at frequent intervals, but, of course, it is necessary to tie up the line of levels to other permanent bench marks to obviate errors due to settlement. Screeds of light boards or scantling are used to aid the inspector and contractor's employees in obtaining the correct slope, and to keep the top level. The screeds are usually set so that the edges of the boards are a foot outside of the correct line. In this way the correct line may be obtained by sighting from one screed to another and measuring down 1 foot; if the screeds are set to the correct line, small protuberances of the stone will prevent sighting from one screed to another.

Following is a brief description of the most important breakwater constructions in the district:

Breakwaters at New Haven. (Fig. 13.) This is a project entirely separate from the project for the improvement of New Haven Harbor proper, and provides for a harbor of refuge at the entrance to New Haven Harbor, to be secured by the construction of three breakwaters, namely: Easterly breakwater, 3,450 feet long, extending from Southwest Ledge to Quixes Ledge; Middle breakwater, 4,450 feet long, extending from a point 550 feet N. 54° E. from Ludington Rock in a direction S. 54° W. across that rock; and the West breakwater, about 4,200 feet long, extending northwesterly from a point 6,000 feet S. 54° W. from Ludington Rock. Work on this project was begun by the construction of the easterly breakwater, commenced in 1880 and completed in 1890. This break-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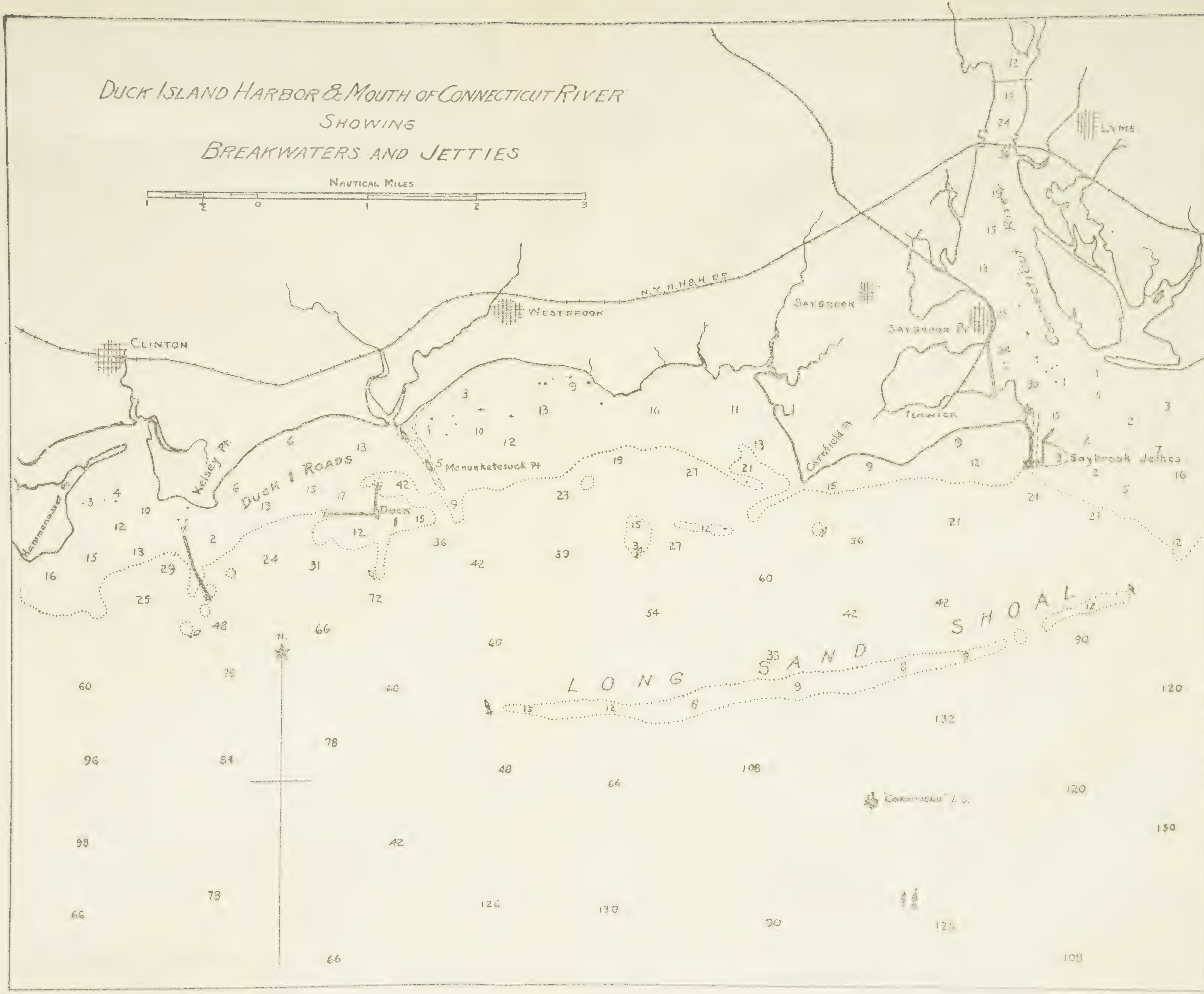

DUCK ISLAND HARBOR & MOUTH OF CONNECTICUT RIVER
SHOWING
BREAKWATERS AND JETTIES
NAUTICAL MILES
CLINTON
WESTBROOK
N.Y. N.H.&H. RR
SAYBROOK
SAYBROOK PT.
LYME
Connecticut River
FENWICK
Cornfield Pt.
Saybrook Jetties
Menunketesuck Pt.
Duck I. Roads
Kelsey Pt.
Hammonasset Pt.
Duck
LONG SAND SHOAL
N.
"CORNFIELD" L.S.

PLATE I.

water contains 293,777 tons of stone, and cost $102.50 per linear foot, including supervision, etc. It is built entirely of riprap with a slightly rounded top, and most of the stone is granite, although some sandstone was used. The Middle breakwater was begun in 1891 and completed in 1895. It contains 339,211 tons of stone. The West breakwater was begun in 1896 and completed in 1915, and contains 492,412 tons of stone. The sheltered anchorage provided by the breakwaters exceeds 2,000 acres, of which over 500 acres is from 20 to 28 feet deep at mean low water and the remainder ranges from 9 to 20 feet in depth. The anchorage is much used by the general commerce of Long Island Sound, as well as by vessels bound to and from New Haven.

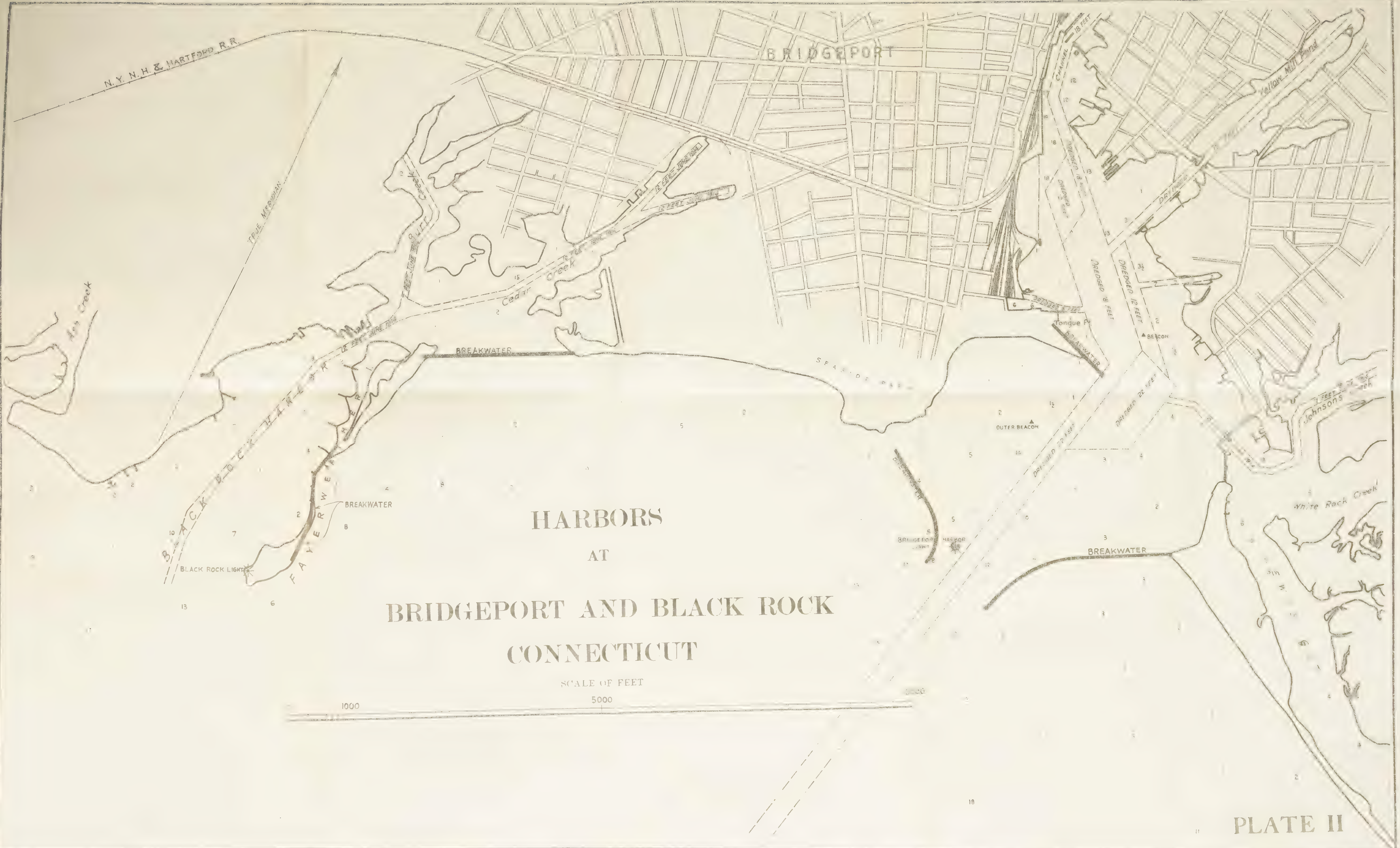
Harbor of Refuge at Duck Island. (See Plate I.) Originally there was no good harbor of refuge between New Haven and New London, a distance of about 46 miles. The result was that the slowly moving tows of coal barges and deeply laden schooners were frequently caught between these ports in bad weather, and many wrecks occurred. Duck Island is located about half way between New Haven and New London. Originally it consisted of an open roadstead which afforded very little shelter except in northerly winds. In 1890 a project was adopted for the construction of three breakwaters to form a harbor of refuge at this point, and one breakwater, that extending westerly from Duck Island, was begun in 1891 and completed in 1898. In 1910 the project was modified so as to omit two of the breakwaters, originally contemplated at the eastern entrance to the harbor, and to provide instead a breakwater extending from Kelsey Point southerly for a distance of 3,750 feet, and a breakwater extending northerly from Duck Island 1,100 feet. The project was completed in 1913. The total amount of stone contained in the breakwaters is 386,352 tons, including a small amount of repair work done in 1915. The total first cost of the work to the end of the fiscal year 1915 was $292,183.84, which is $57,816.16 less than the original estimate. The harbor has proved of great value to the commerce of the Sound, as many as thirty commercial vessels, schooners and barges, seeking refuge at one time.

Bridgeport Harbor. (Plate II.) The first breakwater built at Bridgeport Harbor was begun in 1871 for the purpose of preventing drifting sand from filling in the entrance channel. In 1891-1892 a breakwater, 1,165 feet long, was extended westerly from the "Tongue," so-called, towards the channel, with the ob-

ject of protecting the inner harbor. With the growth of the city the inner harbor became congested and inadequate, and in 1907-1909 the easterly breakwater was extended and a new westerly breakwater was built to protect the outer portion of the harbor. Since the construction of the two outer breakwaters the inner breakwater has ceased to be of use and will probably be removed in whole or in part before long. The two breakwaters last built have been successful, not only in protecting the harbor, but in the preservation of the channel, which has proved to be of unexpected permanence, due to their action. The easterly breakwater is now 2,063 feet long, 8 feet wide on top, 9½ feet high above mean low water, outer slope 1 on 1½ and inner slope 1 on 1. The westerly breakwater is 2,210 feet long, 6 feet wide on top, the height and slopes being the same as those of the easterly breakwater.

Saybrook Jetties. (Plate I.) The construction of jetties at the mouth of the Connecticut River was begun in 1873. Up to that time there were three entrance channels to the river, none of them in very good condition. The object of the jetties was to concentrate the current in one channel and to protect it from wave action. As originally built they were nearly triangular in cross section and suffered considerably from wave attack, so that repairs became necessary several times, and in 1914 the westerly jetty was considerably enlarged in cross section and extended somewhat farther inshore to prevent sand from working across into the channel under the influence of southwesterly gales. The action of these jetties has been very satisfactory and the dredged channel between them, at present 15 feet deep, has proved very stable.

PLATE II


BRIDGEPORT
N. Y. N. H. & HARTFORD R.R.
TRUE MERIDIAN
Ash Creek
Cedar Creek
BLACK ROCK HARBOR
FAYERWEATHER
BREAKWATER
BLACK ROCK LIGHT
SEASIDE PARK
Tongue Pt.
BEACON
OUTER BEACON
DREDGED 18 FEET
DREDGED 12 FEET
DREDGED 22 FEET
BRIDGEPORT HARBOR
Yellow Mill Pond
Johnsons Creek
White Rock Creek
HARBORS
AT
BRIDGEPORT AND BLACK ROCK
CONNECTICUT
SCALE OF FEET
1000
5000
PLATE II

Subaqueous Concrete Work on the Cape Fear River, North Carolina.

BY

Capt. C. S. RIDLEY,
Corps of Engineers.

The canalization of a portion of the Cape Fear River, North Carolina, involves the construction of two concrete locks. Due to the character of the subfoundations and other conditions, it was necessary to seal the bottoms of the lock cofferdams before pumping out. This article is intended to give a description of the concrete work done in sealing the cofferdam, the conditions making it necessary, with the results obtained and conclusions drawn therefrom.

The portion of the Cape Fear River included in the canalization project, lies between the cities of Wilmington and Fayetteville, N. C. Throughout the full distance of 115 miles, the river has a very small slope and, with the exception of a few places, the bottom is composed of sand. Above Fayetteville, the slope increases very greatly and rains in this part of the river produce all of the serious floods in the lower river. These floods are apt to come at any time and no season of the year is exempt from them, although high water prevails generally from January to April.

CONDITIONS AT LOCK NO. 1.

Lock No. 1 is located at Kings Bluff, 39 miles above Wilmington. Here the river banks are about 18 feet high and are composed of a sandy clay which readily crumbles and dissolves where subject to action of freshets and where not supported by vegetation, roots of trees, etc. The width of the river is approximately 300 feet.

As the river is very narrow and is subject to freshets which overflow the banks, and as navigation had to be taken care of during the construction work, it was necessary to build a cofferdam which would be as small an obstruction to the free flow of the river as was possible. This suggested the use of a type of cofferdam which

would follow closely the outline of the lock as is done with foundations of bridge piers. The preliminary borings showed that the sub-foundation would be sand and, as it was considered necessary to inclose this subfoundation positively and effectually to prevent the sand flowing out, and as the head to be sustained was rather high, it was decided to adopt a steel piling cofferdam as best suited to the conditions. The cofferdam, as constructed, consisted of a single row of Lackawanna steel sheet piling anchored back to pine pile anchorages, except at the lower end where "pocket" construction was used. (See Plate I.) It followed the outline of the lock and was generally within 18 inches of the base of the lock walls except at the ends, where the distance was increased to 5 feet.

The investigation of the sub-foundation was made by wash borings and a test pit. The borings showed sand for a depth of about 30 feet below the level of the lock floor. This sand was not uniform at all, but varied from coarse to very fine; the latter, when dried, being almost a powder. To verify the borings and to determine more definitely the character of the sand, a test pit was put down. This was effected by sinking a caisson with water-tight sides and an open bottom. The percolation through the bottom of this caisson was very great and it was recognized that it would be extremely difficult to unwater the coffer. In addition to this, the sand flowed to the pump from all directions, showing the desirability of sealing the bottom of the coffer to be constructed, and also the necessity for permanently enclosing the sub-foundation of the lock to prevent the possibility of the sand flowing out from underneath, after the lock should be completed.

As a result of these investigations it was decided: *first*, to splice the steel piling used in the cofferdam, so that the tops could be easily removed, thus leaving the bottom portions as a permanent cut-off wall around the lock foundation; *second*, to drive bearing piles over the entire area of the foundation; and *third*, to seal the the bottom of the cofferdam with a layer of concrete 6 feet thick deposited under water and enclosing the heads of the foundation piles.

Assuming the elevation of the water surface due to the highest head to be taken by the cofferdam as (+17) and elevation of the bottom of the concrete foundation slab, which seals the cofferdam, as (—15), the maximum upward pressure on the concrete would be 2,000 pounds per square foot. This upward pressure was figured as that due to the head, because the sub-foundation is so highly

water bearing and porous that it was believed safer to consider that the full pressure would be transmitted through it to the bottom of the sealing slab, provided no water flowed into the coffer. When the coffer was pumped out, the slab was practically water-tight. It was noted, however, where the pine foundation piles protruded through the slab, that water was oozing out of the ends of these piles—that is, water was forced into the cofferdam through the longitudinal ducts in the piles.

Of the 2,000 pounds per square foot total upward pressure, approximately 900 pounds was balanced by the weight of the concrete and the remainder was taken up by the foundation piling. As these piles were driven on centers 4 by 3 feet, the total maximum upward pull on each would be about 6½ tons.

Method of Depositing Concrete.

With a view to depositing the concrete in the foundation slab by means of a tremie, the foundation piles were driven in rows across the cofferdam, the successive rows being 4 feet apart between centers. This piling was driven under water by means of extension leads and a follower. This left a free passage between each two rows of piles about 3 feet wide. The bottom of the tremie was about 15 inches in diameter, thus leaving a clearance of about 10 inches on each side of the tremie.

The method of depositing the concrete is shown in Plate II. The progress of the work necessitated putting in the foundation concrete during the flood season of the year. As a consequence, the depth of water through which the concrete was deposited varied from 22 to 34 feet. All of the concrete was made at the mixing plant installed on one of the pockets at the lower end of the cofferdam. The mixer deposited directly into two half-yard self-dumping buckets on "conveying" pontons. There were two of these pontons and they were equipped with windlasses, one at each end, by means of which they were pulled to and from the tremie barge.

The tremie barge was an ordinary deck barge, 20 by 75 feet, at one end of which was installed a stiff-leg derrick with a 45-foot boom. From one line of this derrick was suspended the tremie, and the boom was raised to such a height as to make the tube of the tremie pass close to the end of the barge. The concrete bucket line was run through the same boom at such a point that, when hanging vertical, the concrete bucket would be in position to dump into the

hopper of the tremie. While concreting in the upper end of the coffer, it was necessary to lift the buckets from the pontons with a small unloading derrick at the downstream end of the barge and run it on cars to the upstream end to a point directly under the boom, where it was lifted up by the derrick engine and dumped directly into the tremie. After the work had progressed downstream the length of the tremie barge, the barge was turned around and thereafter the buckets were lifted directly from the barges to tremie by the same engine that handled the tremie.

The tremie consisted of a hopper, middle sections, and a bottom section bolted together through flanges. The middle sections were made of various lengths, so as to provide for different stages of water. These sections were cylindrical and were of a uniform diameter of 12 inches. The bottom section was about 6 feet long and was 12 inches in diameter at the top, but increased in diameter to 15 inches at the bottom. The middle sections were reinforced on the outside by angle irons to provide longitudinal stiffness.

In order that the floor might be as nearly monolithic as possible, it was planned to have the work go on continuously twenty-four hours per day. Stops were made for repairs and high water only. Delays for repairs were of but short duration. At Kings Bluff there was no delay for high water, but at Browns Landing the concrete mixing plant, which was on shore, was entirely submerged by a flood, causing a delay of about one week.

Concreting was started at the upper end of the cofferdam and a layer of the full thickness of 6 feet carried continuously to the lower end. After the full thickness had been obtained at the upper end between the first row of foundation piles and the cofferdam, the tremie was shifted to the second row and from this point on to the end one trip across the cofferdam between each two rows of piles was sufficient to bring it to grade. The concrete being deposited at the top of the slope, as shown in Plate II, flowed down the slope and thus distributed itself in sloping layers. In this way a long lap joint was secured instead of a short vertical joint and the various layers were more or less bonded together.

When first starting, the tremie was rested on the bottom and a batch of rather dry concrete dumped in. There was added also three or four sacks of cement. The tremie tube held something over ½ yard of concrete, so that if the concrete was "washed" only a very small amount would be affected and, by the method of depositing, this would be spread out. The hopper of the tremie held

½ yard. The man at the hopper so managed that the top of the column of concrete was always visible near the top of the tube.

When the tremie is "charged," the concrete first poured into the tube is undoubtedly more or less "washed," and between ½ and 1 yard of concrete is thus affected. If the concreting is carried on continuously, however, and the tremie is carefully handled, there is little need for starting "charges." With the method of depositing, as described above, any washed concrete, except at the extreme upper end of the coffer, would be disclosed at the top of the slab and

The Tremie.

would be spread out somewhat. It would be discovered with the pick when cleaning off for the lock walls and be removed.

With the tremie resting on the bottom, or in concrete just deposited, and the tube full of concrete and all water excluded, the following operations were carried out: A half-yard bucket of concrete was dumped in the hopper, usually filling it. The man at the hopper then signalled the engineman to hoist the tube slightly. This would cause the concrete to run out until the hopper was emptied when, by slacking off on the hoisting line, the movement of concrete was stopped at once. This operation required skill and

care, as the tremie must be raised only a very slight amount, when the pressure of the column of concrete is sufficient to force itself out at the bottom. To move laterally, the engineman moved the boom supporting the tremie, thus dragging the bottom of the tremie through the concrete. When this method brought the tremie to the side of the barge, the tremie was held in place while the barge was shifted laterally its full width. In practice, when the full thickness had been secured at one end of the cofferdam, the concrete was deposited by simply shifting the tremie or by a simultaneous combination of a slight lifting and shifting. As soon as shifting started, the concrete began to run out and when the hopper was empty the shifting stopped until another half-yard was dumped into the hopper. Thus the tube was kept full of concrete at all times and, being water-tight, the concrete reached the bottom in its original state. Four thousand three hundred and twenty-seven yards of concrete was deposited in the foundation at Kings Bluff, under water. This concrete was a 1 : 2 : 4 mixture, and was made rather wet to facilitate the flow through the tremie.

The operation of the tremie offered no special difficulties, with the exception of that due to interference with the foundation piles. These piles were driven under water with a follower and, of course, were not perfectly lined up, so that in some cases there was not sufficient space for the tremie. When such conditions arose, it was usually possible to work around it, but sometimes the tremie "charge" would be lost.

When a "charge" is lost, the concrete flows out of the tube very rapidly and the water rushes in at the bottom and fills the tube. A part of the charge lost is thereby "washed" and rendered useless. It is believed, however, that only that part is washed which is immediately under and near the bottom of the tube. When the concrete flows out, it forms a mound spreading out from the bottom of the tube as a center. When the concrete is nearly all out, the water rushes in and this rapidly flowing water washes a small amount of the concrete just below and adjacent to the bottom of the tube. The flow of water is probably strong enough to carry some of the particles of concrete back up into the tube and wash them thoroughly and, when the movement stops, they settle back on the top of the mound of concrete. It is thought that the greater part of the concrete is not washed nor injured to any great extent while it is flowing from the tube. This theory is borne out by the fact that after the cofferdam at Browns Landing was pumped out, the

Cofferdam at Lock No. 1. After first pump-out, showing concrete floor.

Lock No. 1 at Kings Bluff.

locations of some of the lost charges were disclosed as mounds. When one of these mounds is attacked with a pick, the center is found to contain loose rock and sand covered over with a thin layer of imperfectly set cement. This center, when removed, leaves a small crater surrounded by a rim of perfectly hard and homogeneous concrete.

On account of floods, the coffer was not pumped out as soon as expected and as a result the concrete was about two months old when first exposed. The top of the concrete was found to be covered with about 5 or 6 inches of mud, which had settled to the bottom. Underneath the mud was a thin coating consisting of a mixture of imperfectly set cement and mud. This coating averaged probably ½ inch thick over the whole surface, although it was thicker in the low places. Underneath this scale in the depressions, there was usually found a little loose sand and rock, although in places the scale was directly over the concrete.

On removing the scale and loose rock the surface concrete, for an average depth of 3 or 4 inches over the whole area probably, appeared to be a lean mixture and could be removed without great difficulty with a pick. In one or two places pockets of this weak concrete, as much as 18 inches deep and 4 or 5 feet square, were found, but this was exceptional. Before building the lock walls, this was thoroughly removed, under the base of the walls, by picking and the concrete underneath was found to be extremely hard and homogeneous.

The general level of the surface was good, the maximum difference in elevation between the top of the mounds and the bottom of the depressions being probably 18 inches. It was satisfactory in every way as a foundation for the construction of the lock walls. The lock has been completed and was put in operation in July, 1915.

LOCK NO. 2.

At Lock No. 2, which is located at Browns Landing, 71 miles above Wilmington, the foundation conditions were somewhat different. Portions of the bottom were pure sand for depths of over 40 feet, while in other parts the sand was mixed with clay in thin horizontal sheets varying from ¼ to 1 inch in thickness. At the upper end of the lock, the bottom is sand for a depth of about 6 feet, overlying a sheet of clay about 15 feet thick with sand underneath to a depth of over 40 feet.

As at Lock No. 1, bearing piles were driven over the entire area of the foundation and the cofferdam sealed by a slab of concrete

deposited under water through a tremie. The thickness of the slab was reduced, however, and as actually put in varies from 4 to 5 feet in thickness.

The methods used were entirely similar to those used at Kings Bluff, and the results were just as satisfactory. The cofferdam has been pumped out and the lock walls are now being built. The cofferdam is of the self-sustaining cellular or ''pocket'' type, constructed of Lackawanna steel sheet piling. The total leakage with ordinary stages of water is probably 500 gallons per minute. The

After First Unwatering.

floor slab has been subjected thus far to an upward pressure head of 30 feet.

CONCLUSIONS.

There was a good deal of doubt expressed when the work was started as to the practicability of this method of construction, especially in regard to the probability of securing a tight floor which would resist ''blowing up'' when the coffer was pumped out. All of this work was to be done under water and, on account of the foundation piling, the method of using bottom-dump buckets was impracticable. The area covered was large and a tremie, if used, had to

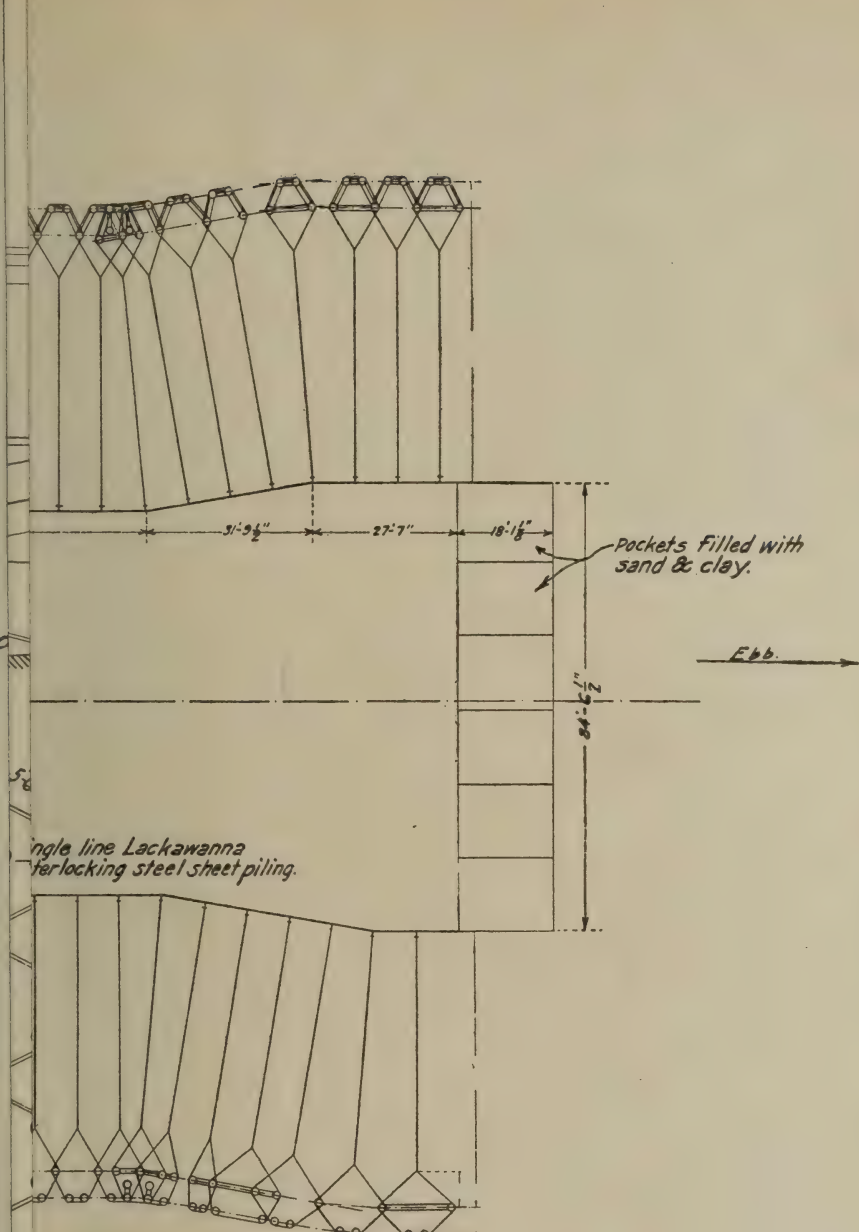
be so moved and operated as to deposit a water-tight floor of uniform thickness to a given grade. It appeared, however, that it was similar to the work which is often done in the construction of bridge piers, except that it was multiplied several times and more care had to be taken in regard to grade.

The success of the work at Kings Bluff seemed to show that the method offered no unusual difficulties. It was carried on during the month of January, night and day, and the weather conditions were extremely unfavorable at times. The river conditions were also

Near View of Concrete Floor of Cofferdam at Lock No. 2, after Cleaning.

bad. Part of the time the cofferdam was entirely submerged, due to floods. The work was done by men who had had no experience whatever with this class of subaqueous concrete work.

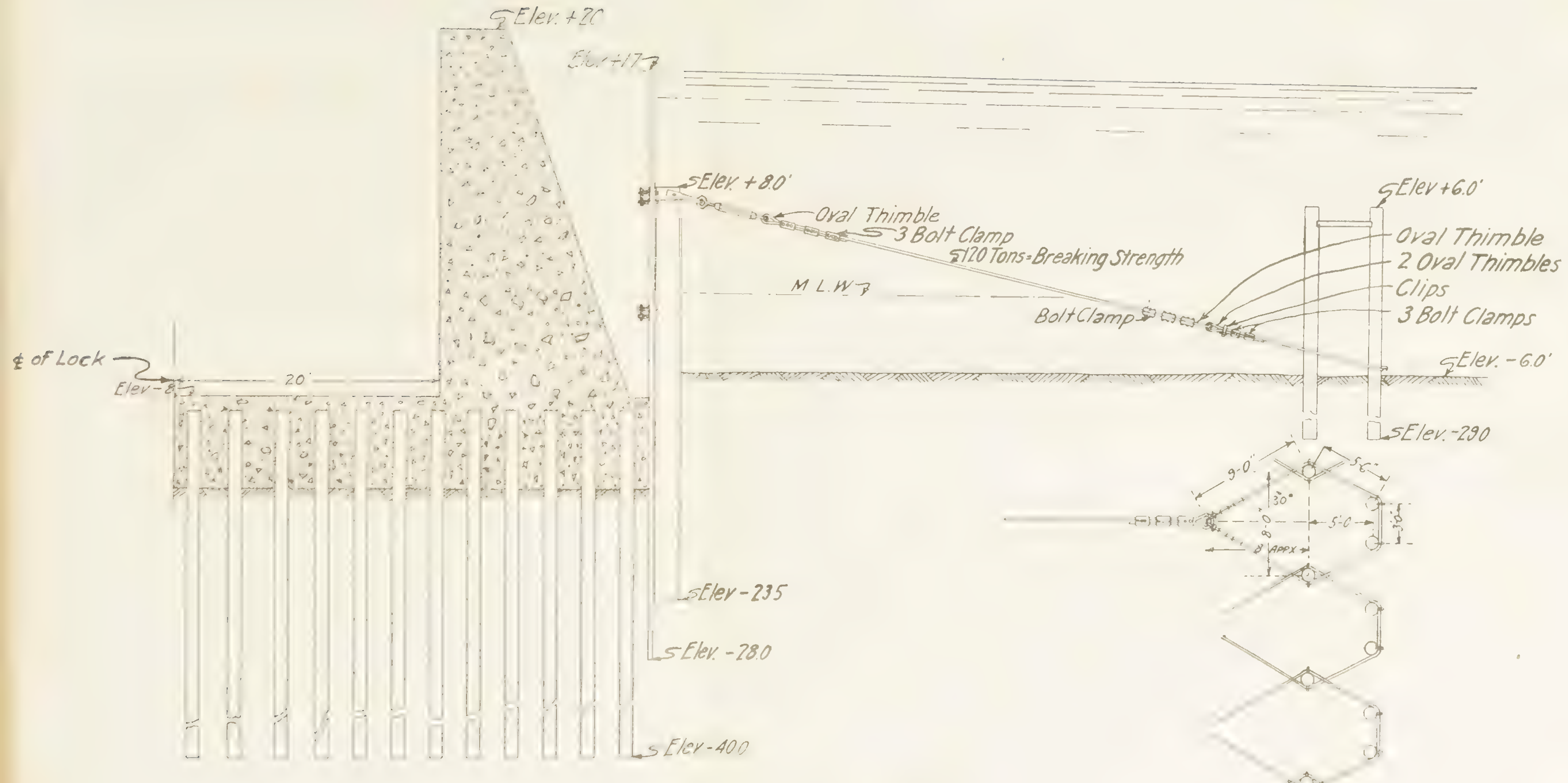
At Browns Landing the men were experienced, but the uniformly good results obtained on this second trial seem to show that it should not be classed as uncertain. It is believed that it can be used in lock construction on sand foundations, in connection with steel cofferdams, with certainty of success and economy, where other types of construction might lead to uncertainty and large unforeseen expenses for maintenance of cofferdam.



Cape Fear River, N. C.,
Kings Bluff.

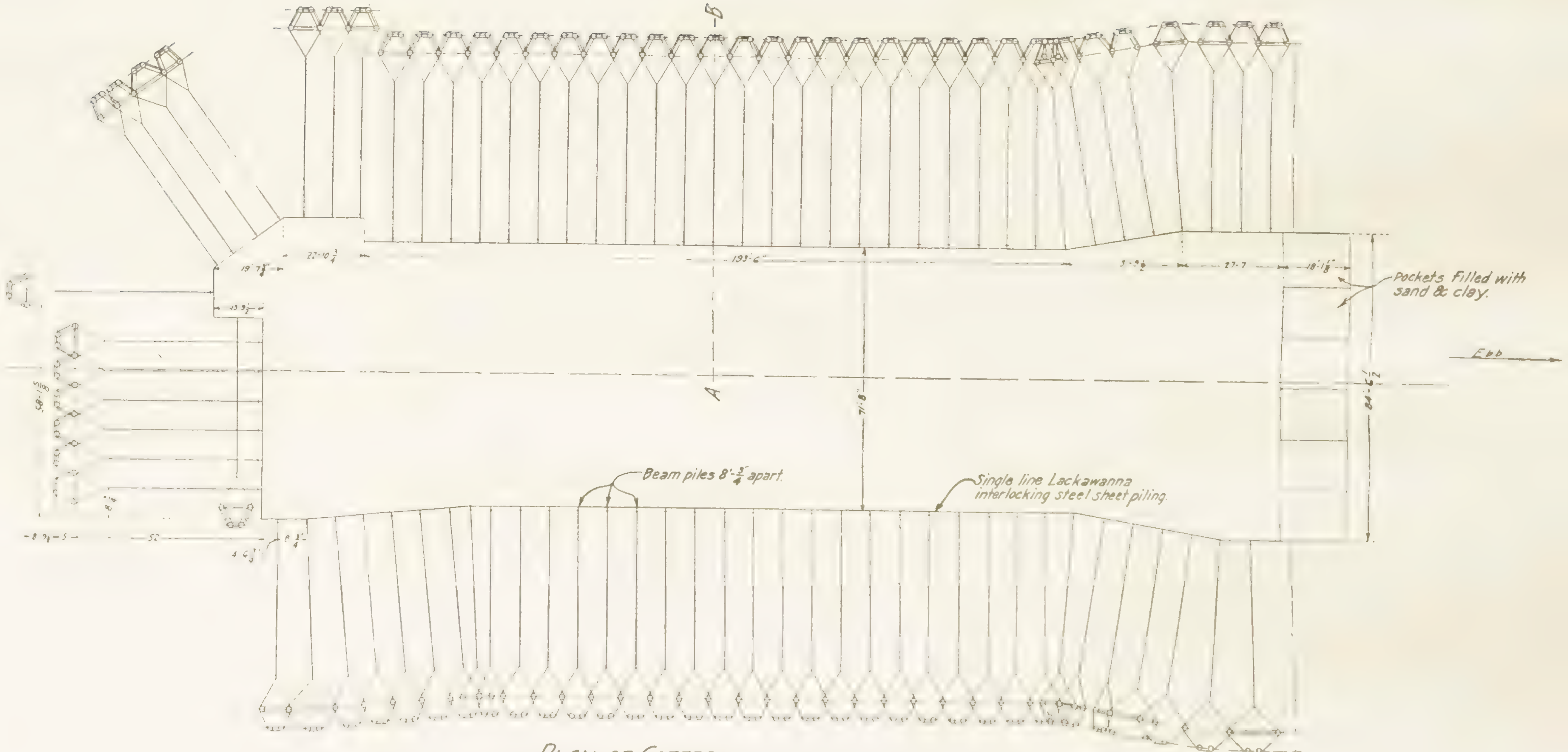
COFFERDAM AT LOCK No. 1.

PLATE I.



SECTION ON A-B. THROUGH BEAM PILE.

SCALE IN FEET.



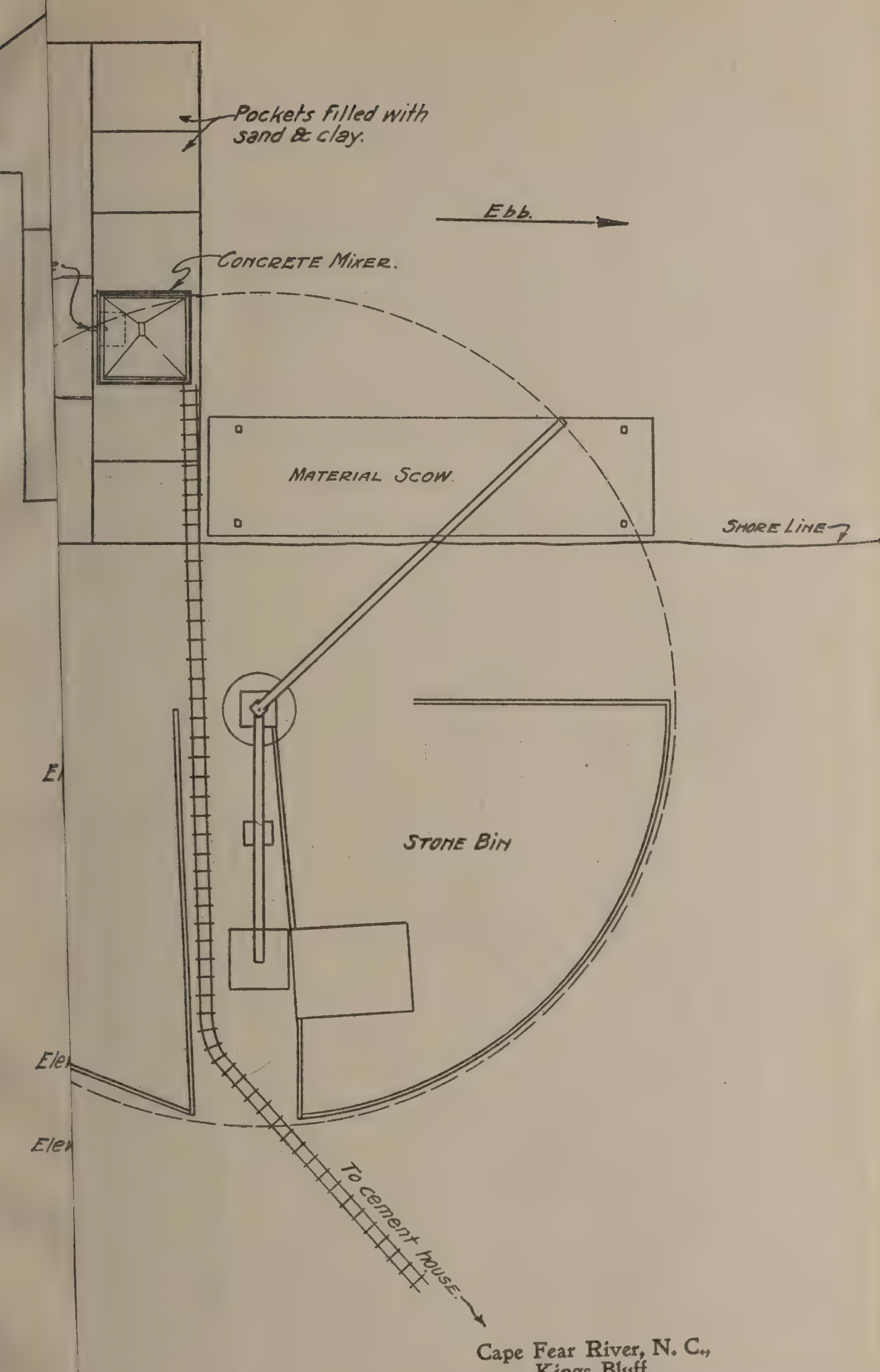
PLAN OF COFFERDAM

SCALE IN FEET

Cape Fear River, N. C.,
Kings Bluff.

COFFERDAM AT LOCK No. 1.

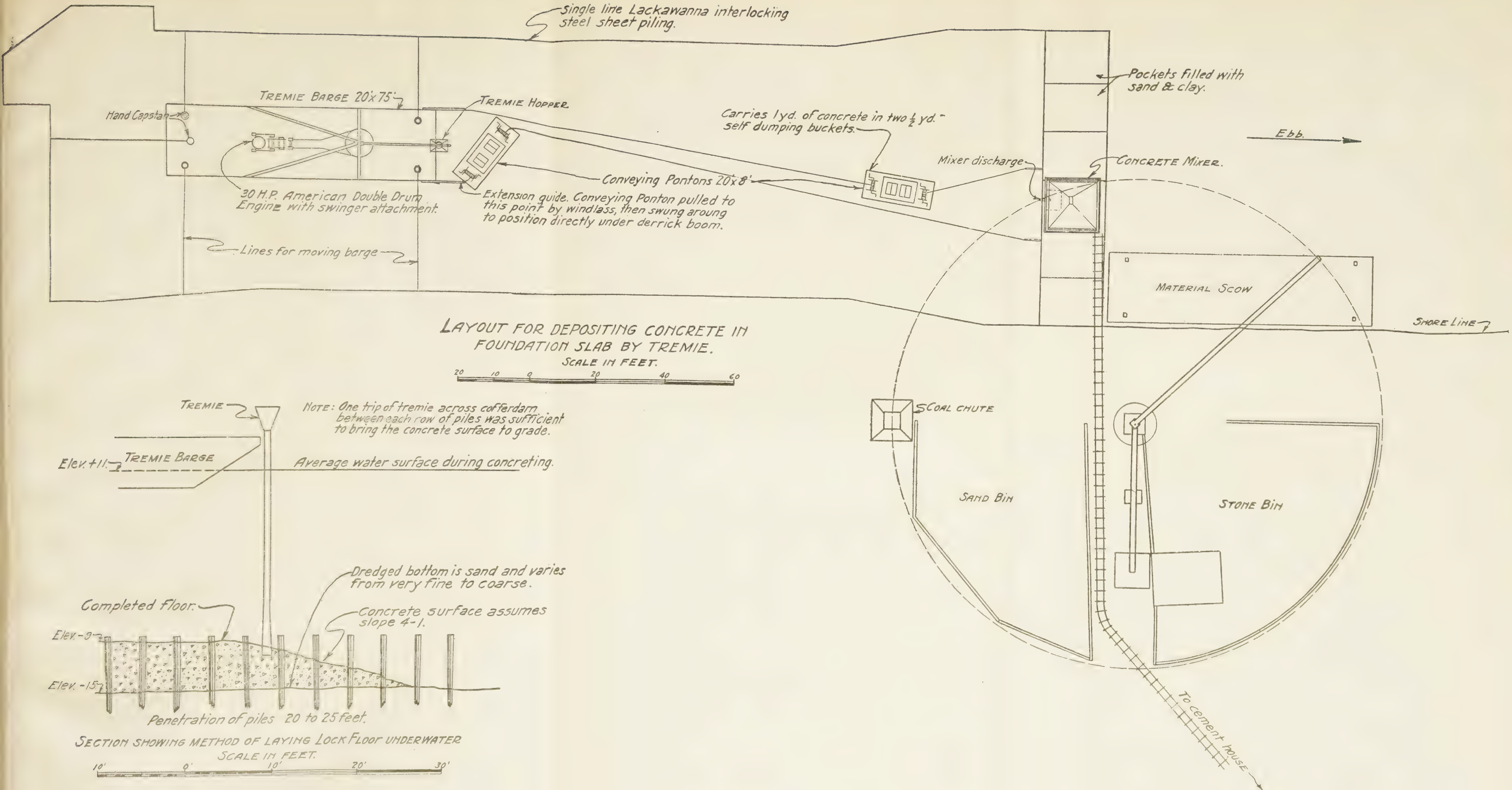
PLATE I.



Cape Fear River, N. C.,
Kings Bluff.

LAY-OUT AND METHOD OF CONSTRUCTION OF LOCK FLOOR AT LOCK No. 1.

PLATE II.



Cape Fear River, N. C.,
Kings Bluff.

LAY-OUT AND METHOD OF CONSTRUCTION OF LOCK FLOOR AT LOCK No. 1.

PLATE II.

Provided the steel can be used three or four times—that is, where there are several locks to build, or, if the steel can be sold to advantage, a steel cofferdam following closely the outlines of the lock with the bottom of the enclosed area sealed by concrete deposited under water before pumping out, will be less costly and more certain of results in sand foundations similar to those found on the Cape Fear River, than the ordinary wooden cofferdam built some distance from the lock walls and pumped out without sealing the bottom.

This applies to the "pocket" or double wall type, as used at Browns Landing. If conditions are such that a single line of piling can be used as at Kings Bluff, shown in Plate I, the cost in favor of the steel cofferdam would be more marked.

Levee Paving With Concrete.

BY

Mr. T. M. McCarroll,
Junior Engineer.

ORIGIN AND HISTORY.

The conditions to be contended with in the maintenance of the levee line below New Orleans are peculiar to that section, and entail a much heavier expense than the relatively small size of the levees would seem to indicate. In the first place, it must be remembered that the spring and summer rises place water on the slopes of the levee and that therefore there is a high water situation to be confronted at least once every year. The water is against the levees for a long period, inducing a moist and saturated condition of the levee which is responsible for a rank and luxuriant growth of weeds and grass. It is necessary to cut the weeds and grass at least twice annually.

Again, the levees are of small cross section and muskrats and crayfish perforate them easily and frequently, thus causing expensive box work for protection during high water and costly excavation and repairs after the water recedes.

Of vital importance to this section is the protection against wave wash caused, in the long periods of duration of high water, by prevailing winds and storms, and by the plying of large ocean steamers increasing yearly in size, speed, and number.

In this section, the general permanency of the bank and the high value of the land have caused the levee line to be built at an average distance of not more than 150 feet from the edge of the bank. The material of which the levees have been built and subsequently enlarged is a sandy deposit, little able to resist the action of the waves. A batture will sometimes chip back as much as 40 feet in a day when the wind is on-shore and the stage of the river favorable for this action.

The universal protection in use on the lower coast up to 1907

was wooden revetment, consisting of 1 by 12 inch or 2 by 12 inch planks placed vertically at the toe of the river slope and fastened to two 2 by 6 inch stringers, the whole making a fence-like structure which is braced to the crown of the levee with 3 by 8 inch braces. The lumber commonly used is pecky cypress; the finished revetment costing from $60.00 to $120.00 per station of 100 feet, and the average life being from five to ten years. This wooden revetment answers its purpose temporarily, but where continued protection is necessary its use is not economical. Moreover, it is liable to damage or destruction by fire; its braces and anchor posts must be renewed every few years; it is dependent for its solidity on the solidity of the levee it protects and when the levee is new or water soaked it does not afford the requisite resistance, and the revetment sways back and forth with the swells. The increase in grade and cross section of the levees is making the bracing of the wooden revetments costly and difficult.

An ideal permanent levee revetment should have the following qualities: It should be durable; it should be solid and reliable at all times; it should reduce seepage through the levee; it should require little repairs; it should be easy to place and easy to remove, requiring little skilled labor in either operation; and it should be inexpensive. After considerable investigation the concrete revetment was decided on as possessing more of these qualifications than any other.

A resolution of November 23, 1906, of the Mississippi River Commission, authorized the construction of concrete revetments on the Bertranville and Socola levees in the Lake Borgne and Barataria levee districts, respectively.

METHOD AND COST OF CONSTRUCTION.

The revetment at Bertranville was constructed in September, 1907, about ten months after the completion of the levee. This revetment for 581 feet was 3 inches thick and had a reinforcement of Clinton wire cloth, 6 by 6 inches, No. 10 wire. The remaining 357 feet was without reinforcement and was 4 inches in thickness. The proportions for the concrete were 1 part cement, 3 1-3 parts sand, and 7 parts gravel. The cost was 84 cents per square yard.

At Socola Levee the revetment was commenced December 27, 1907, immediately after the completion of the levee. The concrete was 3½ inches thick, the proportions for concrete being 1 cement, 5 sand and 8 gravel. The cost was 92.88 cents per square yard.

These revetments consisted of concrete pavement on the slope of the levee from 1 foot above the highest water to the toe of the levee; and a concrete curb extending at the toe of the levee 2 feet vertically into the berm.

In the construction of the revetment, the dry material was wheeled from barges to the top of the levee, there placed in a mixer, thoroughly mixed and placed by chutes and shovels on the slope of the levee in panels of 5 feet width.

Owing to the small allotments for concrete revetment, this method was continued with only minor changes until 1914 and

Illustrates the preparation of the levee slope, placing of forms and location of mixer when the concrete is placed.

1915. During the working season of these years, the cement gun for the placing of concrete revetment was first tried with a view of reducing the cost and increasing the strength of the revetment.

Several methods were tried out, the two giving the best results being as follows: A curbing of machine-mixed concrete 6 inches thick was placed at the river side toe of the levee. This curbing extended down vertically 3 feet into the berm. The slope of the levee was graded and covered from net grade to the inside edge of the curb with 1 inch of washed gravel. The cement gun, operated with a 75-pound air pressure, was placed on top of the levee and

the gunite, as the product of the gun is called, was shot into the prepared slope until a 2-inch thickness had been built up. The second method was practically the same, except that 2-inch mesh poultry wire was placed over the gravel and the gunite applied until a 2-inch thickness had been obtained. The average cost of this 2-inch gunite revetment was 75 cents per square yard.

VALUE AND NECESSITY OF CONCRETE REVETMENTS.

The storm of September 29, 1915, which swept over south Louisiana, brought out very strikingly the relative merits and de-

Illustrates the completed alternate panels, with ''tumble-home'' at top. The construction of the revetment extending 3 feet into the berms is not shown, as a rise in the river covered this portion of the revetment.

fects of the different kinds and forms of revetments, and the absolute necessity of revetments below New Orleans.

The storm was of exceptional severity, and the direction of the wind was such as to cause the maximum wave action. The waves were very high and went over the levees in sufficient volume to carry boats and logs with them. The force of the water was very great.

Where the current was alongshore, densely wooded battures were not only swept clean but the bark was whipped off the uprooted trees. The force with which objects were thrown is evidenced

by large logs that were found fully 50 feet over and on the inside of the levee. A more severe test of the methods used to protect levees against wave action is hard to imagine.

Concrete proved the most nearly successful protection of practicable cost. The thicker and better the concrete, the better was the protection afforded, as might be naturally expected. A 4-inch layer of medium rich concrete appears sufficient for ordinary purposes. While the concrete was badly broken in several places on nearly every revetment, there was no instance of complete failure where the facing was intact when the storm began. The few breaks which occurred were all located where partial breaks existed prior to the storm. The value of even a defective concrete revetment was illustrated at Myrtle Grove. The levee here is at the head of a long reach where the wind had a sweep of from 6 to 7 miles. The batture was low, being generally overflowed even at mean low stages, and almost entirely eroded. In the center was a stretch protected by concrete. On each side were stretches protected by wooden revetments. A large break, about 50 feet wide, existed in the concrete. After the storm the portions protected by wooden revetments were obliterated. The break in the concrete became a crevasse about 400 feet wide. Four days later the ends were held perfectly by the remaining revetment, and the crevasse was kept from deepening by the remains of the toe wall and débris from the concrete, although the water had then a head calculated at 6.0 feet. But for the concrete revetment there would have been probably a crevasse half a mile wide and cut out to sea level.

The relative merits of reinforced and of unreinforced concrete for revetments are still open to question. Neither will stand the impact of logs driven by storm waves. Long continued or violent pounding of logs will cause either to break down. The levee was in no case broken through where the revetment was intact before the storm, whether reinforced or not. A break in unreinforced concrete widens rapidly and requires immediate attention to prevent extensive damage. Reinforced concrete holds together better and allows more time to make repairs. On the other hand, plain concrete is easily repaired, while reinforced concrete is very difficult to repair. It is better to use plain concrete where any willows at all can be grown in front of the revetment and to limit the use of reinforced concrete to those places where the revetment has no screen of trees.

Illustrates the placing of concrete revetment with the Cement Gun. Also shows the location of the gun when the gunite was shot ashore from the gun aboard a barge. The air compressor was located aboard of barge not shown in picture.

Shows the finished revetment in place. The wooden revetment in front is a temporary structure to protect the green concrete from wave action.

Another fact that the storm made evident is that an unreinforced revetment must have considerable mass. The 4-inch revetments broke into large pieces, which fell into the rent and materially assisted in preventing further damage. Six-inch revetment acted proportionately better. The fragments of the 2-inch gunite revetments were too light and were thrown aside by the waves. The open spaces thus left were freely attacked and the damage spread rapidly, generally destroying the entire revetment. On the other hand, some experimental slabs of reinforced gunite stood as well as any revetment on the river. Although badly broken by drift, the reinforced gunite held together, formed a blanket over the earth, and saved the levee intact. An unreinforced gunite revetment adjacent was completely destroyed and about half the earth in the levee was washed away. On the same levee was a stretch of gunite unreinforced and back of a light screen of willows, which limited the free travel of drift to about 70 feet in front of the levee. This revetment was intact.

From the observed facts, the following conclusions are drawn: A revetment less than 4 inches thick must be reinforced. Every effort should be made to grow a screen of willows in front of all revetments. Revetments less than 4 inches thick should be built only where a screen of willows exists to break the force of drift. Concrete revetments placed on a freshly built levee break of their own weight as the levee shrinks, and requires repairs after about a year. Could the levee be allowed a year to settle behind a wooden revetment, a concrete revetment could then be placed and repair costs avoided.

METHOD OF CONSTRUCTION FOR FUTURE CONCRETE REVETMENTS.

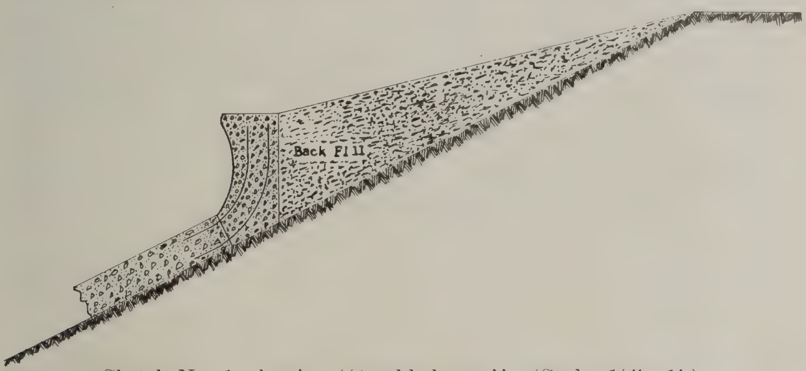
The average cost of concrete revetments placed to date is 86 cents per square yard, subdivided as follows:

	Per cent.
Steamboat charge, installation	4.7
Material—sand, gravel, cement, lumber, etc.	41.4
Labor	42.0
Provisions	7.5
Miscellaneous	4.4
	100.0

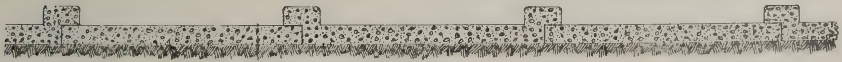
These charges were on revetments of about 8,000 square yards and placed at widely separated locations.

Concrete revetments being now recognized as an urgent necessity, the following plans have been adopted and will be carried out in the future placing of such revetments: Revetments will be so projected as to require at least 18,000 square yards of concrete. A season's work will be so planned as to permit as near as practicable of working in one locality, the extreme limits being confined to a stretch of 10 miles on either side of the river.

Material will be delivered at the work on barges, will be mixed aboard of a barge located at a central point, and placed in industrial cars on the bank by a derrick. The cars will be hauled by small oil-burning locomotives of 3½ tons weight over an industrial track previously placed on top of the levee. The concrete will be



Sketch No. 1, showing "tumble-home." (Scale, ½″=1′.)



Sketch No. 2, showing lap joint to prevent leakage and scour. (Scale, ¼″=1′.)

dumped on the side of the levee and distributed by chutes and shovels into panels 5 feet wide.

With a plant of this kind it is estimated that the main cost of distributing material will be considerably lessened, the cost of the finished work being estimated at from 65 to 75 cents per square yard, depending on the amount and whether reinforced or not. Plate I and Sketches 1 and 2, show the different revetments placed and the revetment that has been finally adopted to overcome all defects brought out by the storm of September 29, eroding battures, shrinking of levee, etc.

The illustrations show the methods pursued in the construction of concrete revetments to date.

Sections 1, 2 and 3 of accompanying sketch show the different forms of revetment constructed to date. (See Plate I.)

Section 4 shows the form of proposed new revetment.

The change in the toe wall was made necessary by the batture eroding back and undermining the wall. The change at the top was made to prevent waves running up the revetment and washing from the top.

The proposed new method of distributing concrete is also shown on sketch.

COMMENTS *by* MAJ. W. G. CAPLES, *Corps of Engineers; District Officer.*

The levee problem below New Orleans is largely one of preventing the destructive effects of wave action. Subsidence of the levees, sudden irregular caving along old outlets, rank vegetation, and boring animals are other factors of more or less importance. Permeable foundations, overtopping, and sloughing are scarcely factors in this reach. The extreme range of the river, small at New Orleans, decreases rapidly toward the mouth of the river while the battures build to nearly the average high water stage, some being still dry at 17.0 feet, New Orleans gage. The levees are consequently low and exposed to but little head of water, enabling a very bad levee to stand for months under conditions that would mean disaster in a few hours above New Orleans.

The waves which destroy the levees are of two kinds, wind waves and steamer waves. The river consists of long straight reaches where the wind has full sweep and creates quite a sea, especially if the wind be upstream—as is the case during the severest storms. Squalls are frequent, while great tropical storms occur at intervals of from six to ten years. The characteristics of the river are so much marine that the reach below New Orleans is known locally as the "Lower Coast." So long as the river is within its banks the waves are broken before they reach the levee and do little harm, but when the river is out of its banks an exposed levee is destroyed in a few hours. Once a storm has commenced, nothing can be done to guard against its effects. Houses swept from their foundations, overturned and destroyed, water tanks blown across the river, trees uprooted and stripped even of their bark, and fishing craft carried entirely over the levees and thrown 50 feet beyond bear witness to the fury of a tropical storm.

Steamer waves are a source of danger, except when the river is well within its banks. During a flood the waves of a great steamer, especially one up-bound, will cut away a levee as rapidly as will storm waves. A continuous passage of vessels at high speed would

Showing the effect of storm of September 29, 1915, on new work at Magnolia, where the batture was wide and heavily covered with trees. The trees are gone and the levee washed away to the crown.

Showing stretch where the batture was narrow and the levee protected by a fence. The remains of the levee on other side of the crevasse are shown.

probably destroy every levee below New Orleans in a day, were the levees protected only by sod. Unlike the storm waves which exert their effect principally near the heads of reaches, steamer waves affect the whole line substantially equally. When the river is just over or just in its banks, steamer waves erode the banks and cut them back on a vertical face of from 2 to 3 feet. This action may extend back 150 feet in a few days and commence cutting into the levee.

The first protection against waves was a wooden fence, anchored to the levee, because its method of failure is to be thrown outward by the pressure of water behind it when the trough of a wave passes. These revetments are effective against steamer waves, but wholly ineffective against a tropical storm, which destroys both levee and revetment almost as quickly and quite as thoroughly as an unprotected levee. The maintenance cost is high, averaging $0.20 per running foot annually at the present price of lumber and is certain to increase as lumber advances in price. Eventually, almost every levee below New Orleans will require protection. The prospect of an annual maintenance charge of $160,000 for a rather flimsy protection and the frequent crevasses at the heads of the reaches led to a search for a more efficient substitute.

The first standard form of concrete revetment (Method No. 1, see Plate I), adopted after trial of plain and reinforced concrete and of both premolded blocks and slabs cast in place, consisted of a 4-inch face paving joined to a 6-inch by 3-foot toe wall. The toe wall was laid continuous, with joints each 25 feet. The face paving was laid in alternate 5-foot slabs, the first slabs making the forms for the remainder. Expansion joints were laid each 25 feet. Various fillers, from pitch to asphalt and numerous patent joint fillers were used without success, all melting and running out. Finally a patent filler consisting of fibre mixed with asphalt or pitch gave satisfaction and was adopted. As the levee shrank, the joint between the toe wall and the face paving opened and waves washing out the earth undermined the slabs. The joint was changed to that shown in Method No. 2. As waves rolled down the face of the revetment they cut a trench alongside the toe wall. When the batture eroded to the toe wall waves striking against this wall caused erosion, sometimes cutting below the wall in a single season. The face-paving was then carried 1 foot underground and the toe wall started from this point. The change served to stop the trouble from the waves rolling down the revetment, but was ineffective against erosion starting at the river. Repairs to a toe wall are hard to make. The Orleans Levee Board still uses the toe wall and extends deeper as required. The United States is experimenting with Method No. 3, which consists in carrying the face paving into the ground for a depth of 4 feet and placing an Elastite hinge at the natural surface of the ground, so that the face paving may rotate freely as the levee settles. Should erosion reach the toe of this paving, repairs can be easily made by extend-

Showing the broken revetment at Potash. The damage here is due to waves cutting out the crown of the levee. The figure illustrates how the slabs fall back, delaying the storm action.

Showing how minor breaks existing at Happy Jack were widened.

ing the paving still further into the ground. Thus far the results have been gratifying, no repairs being required, but the method has been in use only a year, making it too early to give any general statement of results.

Steamer waves running up the face paving attack the levee crown and destroy it, undermining the slabs from behind. The waves during squalls and storms have the same action and cause the largest amount of damage. The Orleans Levee Board and the Louisiana State Board of Engineers, who use reinforced face paving, adopted the expedient of turning up the revetment vertically for a height of 4 inches. Net grade is 5 feet or more above the average stage at which wave action is generally worst; hence the wave (unless a storm wave) running up the levee becomes very thin and a 4-inch tumble-home is sufficient. The form shown in Method 3, Plate I, was adopted by the United States, it being slightly cheaper to construct and being required because no reinforcement is used in the face paving. Another source of trouble from steamer waves is "pumping" at the joints. Where the joint is not filled, the earth becomes soft and runs out when the trough of a wave passes. The trouble is aggravated by vegetation growing in the joints. The space left by the earth which first runs out is filled with water which converts other earth into a mud that runs out until, finally, the paving is undermined and breaks. Filling each fifth joint with Elastite and the remainder with slater's felt has remedied the trouble, but whether the remedy is permanent remains to be seen.

The storm of September 29, 1915, showed that nothing short of a sea-wall can withstand the full fury of such a gale, but by proper design much may be done in the way of lessening storm damage. The failure of concrete revetments was due to two causes: Battering to pieces by drift, and washing out of the levee behind by waves carried over the revetment. The latter action starts on the crown of the levee, where a pot-hole is washed out until the concrete breaks and falls in. The top of the levee is then washed away and the action is repeated on the new crown until either the storm ceases or total failure results. The effects of this action, varying from incipiency to complete failure, could be plainly observed after the storm.

The photographs of the damage, printed in this article are, unfortunately, poor, all films having become damp during the storm and no dry ones being available for some time thereafter, but some idea of the storm effects may be obtained from them.

Previous to the storm, concrete revetments existed only in the worst exposed locations, where every storm destroyed the fences and levees. The surprising thing is that the concrete stood as well as it did. Wherever a good belt of trees existed previous to the storm the concrete was undamaged, showing that if the drift be held in check the waves can be cared for. Whenever the batture was 150 feet wide the damage was minor, although the river was out

Shows effect where the wind was along-shore. The levee is washed out behind the partially destroyed fence. Under similar conditions concrete revetments suffered no damage.

The wind here was also along-shore, and neither fence nor concrete existed. The levee was entirely destroyed.

of its banks at the time; hence the conclusion is drawn that with a batture 150 feet wide and covered with trees, but little damage is to be expected if the levee is covered with concrete. The probability of a storm's coinciding with high water is about once in from 300 to 400 years. Obviously, it is uneconomical to build for such a contingency. The decision has been made, therefore, to keep the levees 150 feet from the river, to encourage the growth of willows on the battures and to build to resist only the ordinary storms. Fences are to be abandoned, except as temporary expedients to allow the levee to settle before placing concrete, thus avoiding heavy repair bills for concrete cracked by the settling of the levee.

The important change in design caused by the storm is to give the "tumble-home" a height of 1 foot. The Orleans Levee Board is trying a vertical face. The United States will experiment with a curved face (Sketch No. 1, ante), designed to throw the waves away from the levee. Thus far no one is willing to undertake the expense of paving the crown of the levee until the efficiency of the new "tumble-home" has been tested. Where the prevailing storm winds are alongshore, the United States will adhere to plain concrete, because repairs on it are easy and cheap, while on reinforced work they are difficult and expensive. At the heads of reaches, where any revetment short of a sea-wall will probably be destroyed by the force of the drift carried by the waves, it is proposed to use a 6-inch reinforced face to better resist the action of drift and to give a covering which, even if shattered, will hold together enough to prevent a crevasse. The probable life of such a revetment, considering storm frequency and average river stages, is from 80 to 100 years, assuming that a storm occurring with the water just over or just in its banks will destroy the revetment. "Pumping" being the most prolific cause of repairs, it is proposed to test a covered joint between slabs (Sketch No. 2 ante) which, it is hoped, will eliminate this trouble permanently.

Considerable attention has been given in recent years to paving methods. Contract work gave too much unsatisfactory concrete and a resort was had to hired labor. The principal cost, outside of the material, is the handling from the barge to the levee. The first method tried was wheeling in barrows, but it was so expensive that some other means had to be sought. Blowing the material with the cement gun works well but, the coating being a mortar, no advantage can be had of the economy gained by the use of coarse aggregate. Pneumatic concrete mixers appear unsuitable because of the cost and difficulty of renewing large pipes. During the past season the aggregate was loaded into carts by a derrick boat, hauled and dumped on the levee. A practical difficulty with this plan is that the carts are needed on the plantations at the same time, and but inferior animals can be rented. A resort to mechanical traction is indispensible to avoid delays in a working season that averages five months and is rarely over six. The introduction of mechanical traction involves also a change from mixers traveling on

the levee to a central mixing plant, because with mechanical traction it is cheaper to send out the mixed concrete and chute it from cars than to move the mixers on to and along the levee and feed them by hand. With a levee crown of only 8 feet the practical difficulties of storing aggregate and moving mixers are great and will be eliminated by sending out mixed concrete from a central plant.

Below New Orleans, the paving of levees will involve the handling of about 350,000 cubic yards of concrete and the digging and backfilling of about 700,000 cubic yards of earth. Above New Orleans an as yet undetermined amount of paving will have to be done. Steamer wash is troublesome and increasing as far up as

Myrtle Grove Crevasse with the ends held by the concrete, and the water falling over the toe wall left in place.

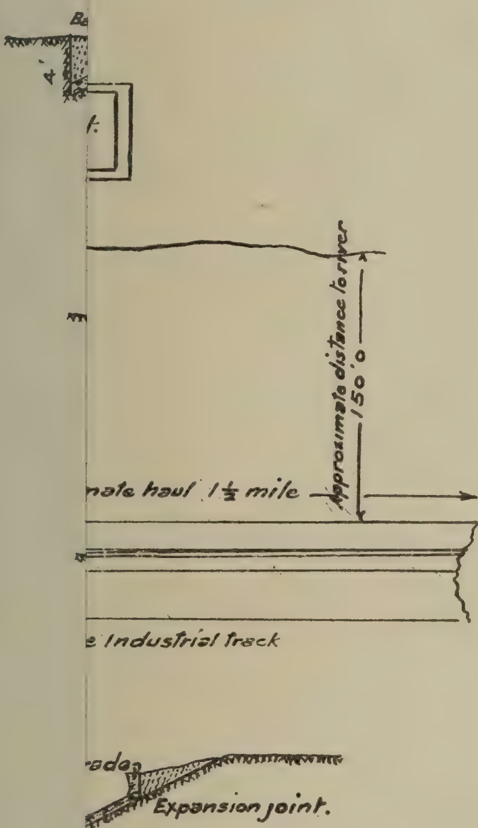
Baton Rouge, while other causes necessitating paving exist in scattered locations. The total amount of paving ultimately required above New Orleans is likely to be more rather than less than that required below. Suitable plant and methods can therefore effect very important economies and are being given careful study. The proposed general arrangement as now tentatively outlined is the following:

A suitable dredging and screening plant will be installed to provide aggregate to both levees and revetments and permit the use of a properly graded mixture giving better and cheaper concrete than is possible when using run-of-bar sand and gravel.

The aggregate and cement, in barges, will be brought to a floating mixing plant similar to that now used on bank revetment work where the materials are handled mechanically. A trestle, tracks, engines and cars will be used to convey the concrete, which will be loaded by a floating derrick into cars and placed on the levee by chutes. But one set-up of the plant for each 2 miles of paving is anticipated. The work of excavation and back-filling for the slope below the ground surface will probably be done by a machine. The digging is most readily accomplished by a drag-line because of the cramped location and the necessity of backing away from the work, as the ditch starts at the levee toe. The back-filling, for the same reasons, must be done by a push rather than a pull. Either a dipper or a clam-shell alone will serve, but present study indicates that the machine will likely be a small caterpillar-mounted crane arranged to operate alternately a drag-line and a dipper.

Although concrete revetments are designed primarily to resist erosion, they have incidental features of great advantage. No matter how high the water may come the levee does not seep. The concrete carried into the ground is superior to any ordinary muck ditch. Old, leaky and sloughing levees treated with concrete cease to give trouble and the bog holes back of them are transformed into dusty roads. Among "high-water fighters" it is axiomatic that a dry levee is a safe levee.

PLATE I.



MISSISSIPPI RIVER COMMISSION
FOURTH DISTRICT

OWING METHODS IN USE FOR PROTECTING
EES FROM WAVE WASH & CONCRETE REVETMENT
Scale 1" = 10 Feet.

ical report dated April. 1916.

J. M. McCarroll
Junior Engineer

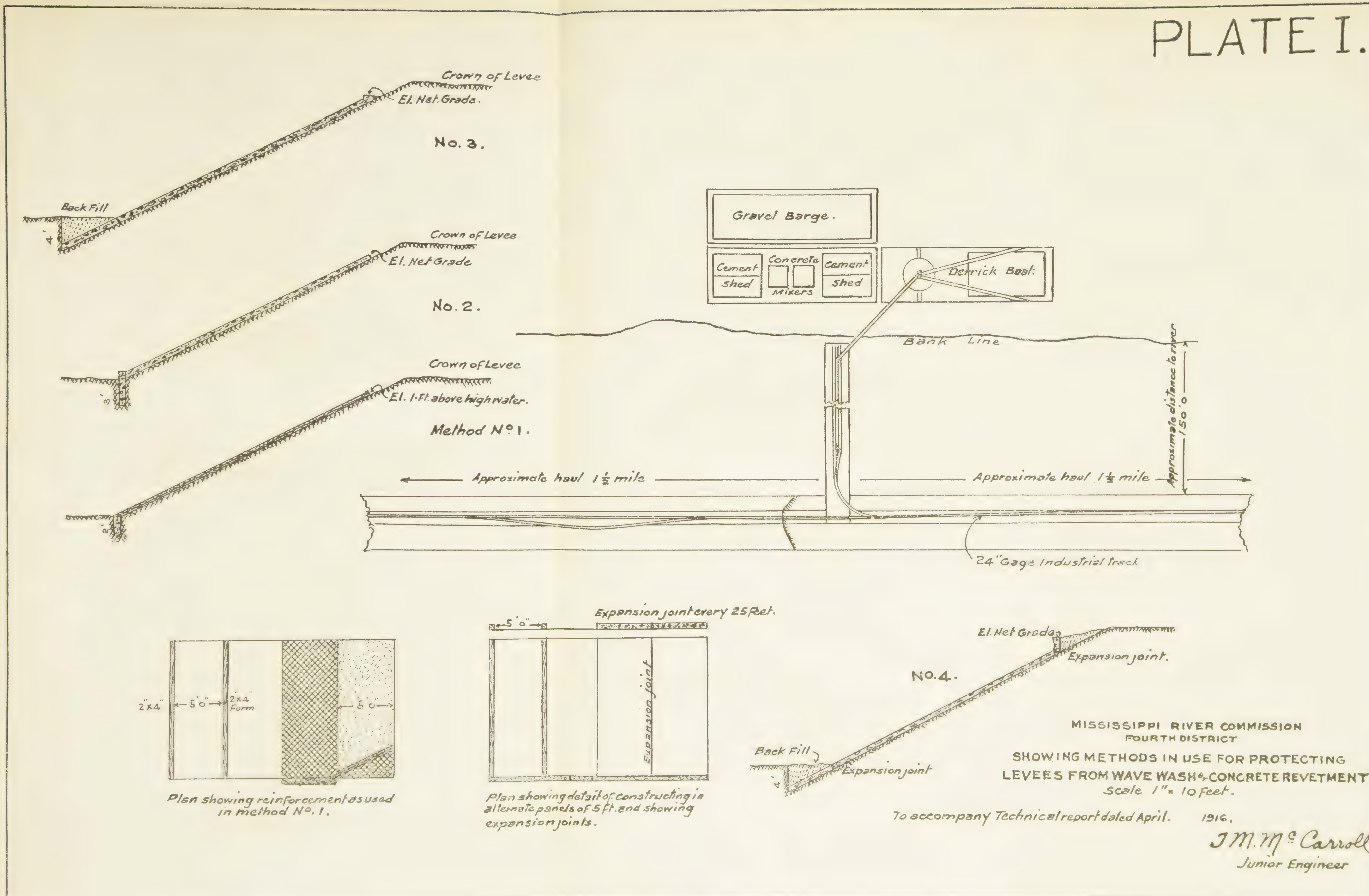


PLATE I.
Crown of Levee
El. Net Grade.
No. 3.
Back Fill
4'
Crown of Levee
El. Net Grade
No. 2.
3'
Crown of Levee
El. 1-Ft. above high water.
Method N° 1.
2'
Gravel Barge.
Cement Shed
Concrete Mixers
Cement Shed
Derrick Boat.
Bank Line
Approximate distance to river 150'0
Approximate haul 1½ mile
Approximate haul 1½ mile
24" Gage Industrial track
2"x4"
5'0"
2"x4" Form
5'0"
Plan showing reinforcement as used in method N°. 1.
5'0"
Expansion joint every 25 Feet.
Expansion joint
Plan showing detail of constructing in alternate panels of 5 ft. and showing expansion joints.
El. Net Grade
Expansion joint.
No. 4.
Back Fill
Expansion joint
4'
MISSISSIPPI RIVER COMMISSION
FOURTH DISTRICT
SHOWING METHODS IN USE FOR PROTECTING
LEVEES FROM WAVE WASH & CONCRETE REVETMENT
Scale 1" = 10 Feet.
To accompany Technical report dated April. 1916.
J. M. McCarroll
Junior Engineer

Box Cofferdams on the Ouachita and Big Sunflower Rivers.

BY

Mr. T. C. Thomas,
Assistant Engineer.

(*a*) OUACHITA RIVER.

The only box cofferdam so far used on the Ouachita River is the one built to inclose Lock No. 3, near Riverton, La.

This cofferdam was 19 feet in height for the greater part of its length, placing its top at an elevation corresponding approximately to a 14-foot river stage. The puddle fill, a clayey sand, was 16 feet thick. The underlying material varied from a clayey sand at the surface, through clean sand and a sand and gravel mix, to blue clay at something over 30 feet below the river bed. The coffer framing consisted of six lines of 6 by 8 inch waling with 2 by 12 inch verticals, and 1-inch tie rods at 8-foot centers horizontally; three lines of 4 by 4 inch horizontal struts on same centers as the tie rods were used temporarily, being removed as the coffer fill progressed. The vertical spacing of the wales and tie rods varied from 2 feet 6 inches at bottom to 4 feet at top. The coffer sheeting was of 2 by 12 inch plank, with an average penetration of 2½ feet into the river bed. The cofferdam was placed about 3 feet from a line of permanent triple-lap sheet piling inclosing the lock on the river side and ends. This sheet piling had an average penetration of 27 feet; and rose to within 6 feet of the top of the coffer. The sheet piling paralleling the river wall of the lock was to be cut off at low-water mark after the removal of the cofferdam, but a stage sufficiently low for the purpose has not occurred since the taking out of that structure, in December, 1914.

The sheet piling across the ends of the lock was removed, down to the lock floor, in December, 1914. The triple-lap piling, below the final cut-off, is in contact with the concrete, to which it is anchored at 1-foot intervals horizontally, and forms a part of the

permanent lock construction. No special effort was made to fill the space between the triple-lap piling and the coffer, but in the process of filling the coffer with material excavated from the lock pit, this space was filled nearly to the top of the piling with droppings from the dredge buckets. The triple-lap piling, and the earth seal between it and the coffer, should be considered as a part of that structure, or as supplementing it, taking the place of the outside and inside embankments generally used. Details of the cofferdam are shown on Plate I.

The upstream end and river side of the cofferdam was placed during August and the early part of September, 1913. Operations were suspended in middle September, 1913, on account of unusually high water, and not resumed until October, 1914; the coffer being completed from the 15th to the 20th of that month. Before the cofferdam was submerged in 1913, round fender piles were driven at 20-foot intervals along the outside wall, and 53 cubic yards of light riprap was deposited around the upper outstream corner, as a protection against scour.

The coffer skeleton, consisting of 2 by 12 inch sheeting bolted to the waling at 8-foot intervals, was assembled on a raft and barge, and launched by supporting the successive panels with a derrick while the raft was moved back to clear, then lowering the framing to place. The details of the process are illustrated on Plate I. The 2-inch sheeting was pressed into the river bed by resting a No. 2 Warrington steam hammer (6,500 pounds) on the successive strips, then spiked to such wales as were above water. The puddle fill was excavated from the lock pit with an orange-peel dredge, digging the material and depositing it in the coffer with one handling.

The coffer skeleton, 640 feet in length, was placed in twenty-four working days, the sheeting in the same number of such days; the two classes of work overlapping as far as practicable. The greatest length of coffer framing placed in one day was 48 feet.

From middle September to December, 1913, there was a scour of from 2 to 3 feet along the outside of the coffer, increasing to 5 feet at from 20 to 40 feet out; and at the beginning of the following working season the structure was found to be in an unsatisfactory condition. The following is quoted from the report of operations at Lock and Dam No. 3 for the month of October, 1914:

> The part of the cofferdam which was built last year has been undermined and is tending to slide out into the river. This has been stopped to some extent by the anchoring of the cofferdam to the permanent sheet piling with 1¼-

inch rods. This seems to hold the top, but the bottom has gone out into the river about 2 feet. The cofferdam will not hold over a 5-foot stage in its present condition.

Work was prosecuted inside the cofferdam from latter part of October until early December, 1914, in which time the river wall was concreted to about half height, furnishing support to the triple-lap sheet piling and the adjacent cofferdam, and a floor section at downstream end of lock was placed. December 1 a sharp rise set in and work inside the cofferdam was abandoned on the 9th, when the river stage was practically 9 feet, and the head on the bottom of the excavation immediately inside the sheet piling at the ends of the lock was about 17 feet. Under the final conditions, the percolation, which was confined largely to the ends of the lock pit, reached the capacity of the 8-inch centrifugal pump installed for unwatering the cofferdam, and the top of the triple-lap sheet piling, where not supported by concrete, was forced inward—in some places as much as 3 feet.

The work had progressed, however, to a stage where the river wall could be used as part of a cofferdam, leaving only the ends to be closed, to enable the lock pit to be unwatered and the work completed. The box cofferdam was taken out in December, 1914, and the lock ends closed by a "puddle-wall" cofferdam in 1915. Views are given showing the cofferdam at various stages of its history (Figs. 1, 2, and 3).

The labor forces employed in building the cofferdam, puddling excepted, with the corresponding cost of services and subsistence, were as follows:

Placing Coffer Framing.

1 foreman, at $3.00	$3.00
1 engineman, at $2.50	2.50
1 stoker, at $1.50	1.50
18 laborers, at $1.65 each	29.70
	$36.70
21 rations at $0.50 each	10.50
Total cost per day	$47.20

Placing Coffer Sheeting.

1 foreman, at $3.00	$3.00
1 engineman, at $2.50	2.50
1 stoker, at $1.50	1.50
9 laborers, at $1.85	16.65
	$23.65
12 rations, at $0.50 each	6.00
Total cost per day	$29.65

The puddle fill was placed by the usual force for an orange-peel or clam-shell dredge. A statement of the cost of the cofferdam is given in Table II and III.

(*b*) BIG SUNFLOWER RIVER.

At the Big Sunflower River Lock, Little Callao Landing, Miss., there was used a modified box cofferdam; the inner wall consisting of deeply driven triple-lap sheet piling, the outer wall being of the usual *box* construction. The height of the cofferdam was between 11 and 12 feet, and the top, at the outer wall, was at an elevation

Fig. 1. Cofferdam partly completed, puddling in progress. River stage, 1.5 feet (18.3 elevation).

corresponding to a 7-foot river stage. The puddle fill, a clayey sand, was 10 feet thick. The underlying material varied from a comparatively shallow stratum of sandy clay at the surface, through clayey sand and pure sand, to sand and gravel at about 30 feet below the river bed.

The triple-lap sheet piles were built of 3 by 12 inch planks with 4 by 12 inch planks between. This piling was driven to an average penetration of 26 feet; and the portion below the final cut-off, at low-water mark, was left as part of the permanent con-

struction, being in contact with the lock concrete and anchored thereto. The waling of the outer wall consisted of 6 by 8 inch timbers arranged in three rows. The sheeting was composed for the most part of 3 by 12 inch planks, although some 2-inch stuff was used. The coffer walls were tied together with a jointed system of eye-bolts, shackles and eye-rods, to facilitate the placing of the coffer framing. Details of the structure are shown on Plate II.

Following is an outline of the method of placing the cofferdam

Fig. 2.

framing: The holes for the eye-bolts at the inner wall of the cofferdam were bored beforehand in every sixth sheet pile, the location of the holes having been determined from a study of the penetration of test piles driven in 1912. When, in driving the tie pile, any one of the holes passed below the guide wale, an eye-bolt was pushed through and secured by bolting to an 8 by 12 inch block, long enough to bear on four sheet piles. The tie rods, linked with the eye-bolts, were temporarily secured to the sheet piling already driven in such manner as to be readily accessible. The framing of the outer wall, consisting of the waling and strips of

sheeting at 6-foot intervals, was assembled on a platform built on the side of a 25 by 100 foot barge. A top wale was suspended, at the proper height, by light chain-hoists supported by trolleys running on a rail that rested on brackets secured to the side of the house on the barge. The sheeting strip at the mid-point of the wale, and the ends of the adjacent top wales with their corresponding sheeting strips, were secured to the hanging wale by the shackle eye-bolts used at the outer wall of the coffer. The second and third wales of the panel under construction and the ends of

Fig. 3.

the corresponding wales of the adjacent panels were then secured to the sheeting strips, the bottom wales resting on the platform. The barge was then shifted back, and the assembled panel slid down a sloping way at the end of the platform; the chain hoists being run forward and slacked off as the barge was shifted. When any eye-bolt reached the water surface, the corresponding tie rod was swung over from the inner wall of the coffer and linked with the eye-bolt shackle. When the panel was lowered to the river bed the chain-hoists were detached and run back into position for the next panel. The intermediate strips of sheeting were then placed

and pressed into the river bed about 2 feet, by resting a No. 2 Warrington steam hammer on their tops, then spiked to all wales above the water surface. The greater part of the puddle fill was excavated from the lock pit with an orange-peel dredge and deposited in the cofferdam at one handling, the remainder being taken from the river bed some distance below the lock site and barged to the coffer.

The cofferdam was built June 19 to July 25, 1914, work on the structure not being continuous. The inner wall (407 feet long) was driven in the equivalent of twenty-four 8-hour shifts of one driver

Fig. 4.

crew; the coffer skeleton (447 feet long) was erected in ten shifts—the maximum length of framing built in any one shift being 85 feet. The sheeting was placed in eleven shifts of one driver crew. Fender piles were driven later along the outside of the cofferdam at 12-foot intervals to a penetration of 12 feet. Views of the cofferdam are shown. (Figs. 4, 5, and 6.)

Construction work was prosecuted inside the cofferdam from the latter part of July, 1914, until the end of the following October, in which period the lock foundation was prepared, the lock floor concreted and the walls built to about two-thirds full height—

or to an elevation corresponding to an 11-foot river stage. The progress made being sufficient to permit the completion of the lock in a cofferdam consisting of the river wall and the two guard dams, the outer wall of the box cofferdam was removed in November, 1915. The inner wall of triple-lap sheet piling was afterwards cut off at low-water mark.

The maximum head on the cofferdam, during the time it was unwatered, was 11 feet. The highest river stage for the period was 2 feet, a zero stage obtaining the greater part of the time. The percolation was moderate, as far as it could be definitely observed.

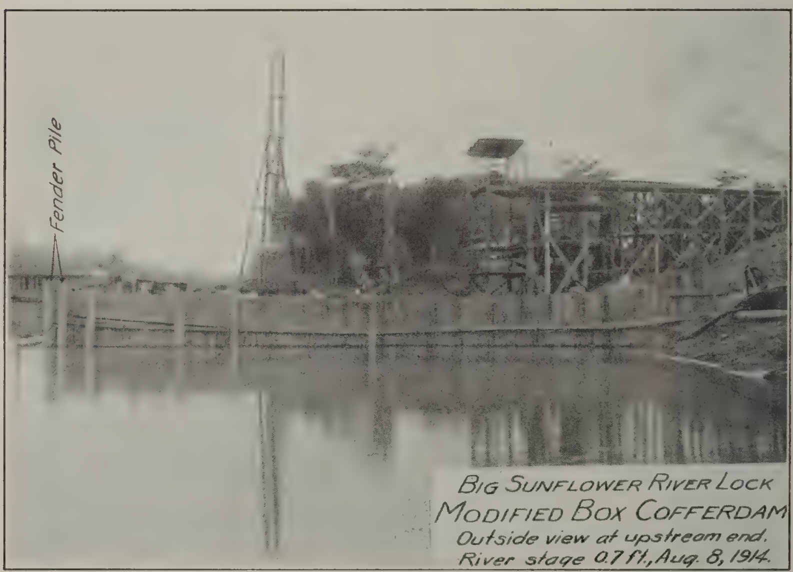


Fig. 5.

There were a great many strong boils in the lock pit, but as the temperature of the water from these was 60° F. when the river water tested 78° F. they evidently proceeded, in large part, from an underground flow tapped by the foundation piles.

The only unsatisfactory feature that developed in this cofferdam was heavy settlement of the outer wall, as compared with that of the inner one, causing a rather marked leaning of the whole structure towards the outside. It may be noted, however, that this cofferdam was never subjected to any decisive test, the maximum head that actually obtained being considerably less than that which the structure was designed to withstand.

The dam at Little Callao Landing was built, in 1915, in two cofferdams essentially like the one used for the lock, and described above; except that the outstream end of the one built contiguous to the lock, and about 30 feet of the upstream and downstream sides adjacent to the outer end, was constructed as a regular puddle wall coffer, the shiplap piling used in the outer wall being driven to a 12-foot penetration. These cofferdams were satisfactory, but again there was no severe test. A 9-foot rise occurred in September, 1915, when work inside cofferdam No. 2 was practically completed and its removal was in progress. The freshet caused a scour of about 5 feet around the outer end of the cofferdam—a scour that would be disastrous to the usual box cofferdam with the light penetration commonly obtained for the wall sheeting.

The special organization used in constructing the lock cofferdam and labor cost per day, were as follows:

Placing Framework.

1 foreman, at $3.00	$3.00
4 laborers, at $2.00 each	8.00
4 laborers, at $1.75 each	7.00
9 rations, at $0.50 each	4.50
Total	$22.50

Placing Sheeting.

1 foreman, at $3.00	$3.00
1 engineman, at $2.50	2.50
1 stoker, at $1.75	1.75
3 laborers, at $2.00 each	6.00
3 laborers, at $1.75 each	5.25
9 rations, at $0.50 each	4.50
Total	$23.00

The cost of the lock cofferdam is given in Table II.

REVIEW.

The Ouachita and Big Sunflower rivers are streams of comparatively small cross section, with beds of permeable and subject to erosion material in the general case. The banks are stable under normal conditions, but the equilibrium is a delicate one, and artificial obstructions are apt to cause marked changes in the river section. It is the last-named feature that caused the abandonment of a clearance between the cofferdam and the permanent work, and led to the inclusion of the subaqueous parts of the inner wall of the

cofferdam with the permanent structure, as illustrated by Plate II and and Fig. 8; the governing idea being to reduce, to a minimum, the contraction of the river section. The same feature controlled largely the design of box cofferdams for these rivers, leading to the substitution of a deeply driven line of sheet piling as close as practicable to the cofferdam, or as one wall of the structure, for the fill usually placed against the outer and inner walls to increase stability and the percolation resistance. The later practice in lock construction on the Ouachita River is to build first the river wall and the end section of the land wall to about half height,


BIG SUNFLOWER RIVER LOCK
MODIFIED BOX COFFERDAM
Inside view. Note the anchor blocks for the tie rods. River stage 0.7 ft. Aug. 8, 1914.

Fig. 6.

place the end sections of the lock floor and install the guard dams; the foregoing to be accomplished during the first season's work inside the cofferdam—natural conditions permitting—removing the cofferdam at the end of the season and afterwards completing the work in the coffer formed by the partially built river wall, land-wall ends and the guard dams. The object of this method of construction is to avoid having a cofferdam in place during the high water season, and thus prevent, in large measure, the scour consequent on an obstructed river section during a period of heavy discharge.

This program was successfully carried out at the Big Sun-

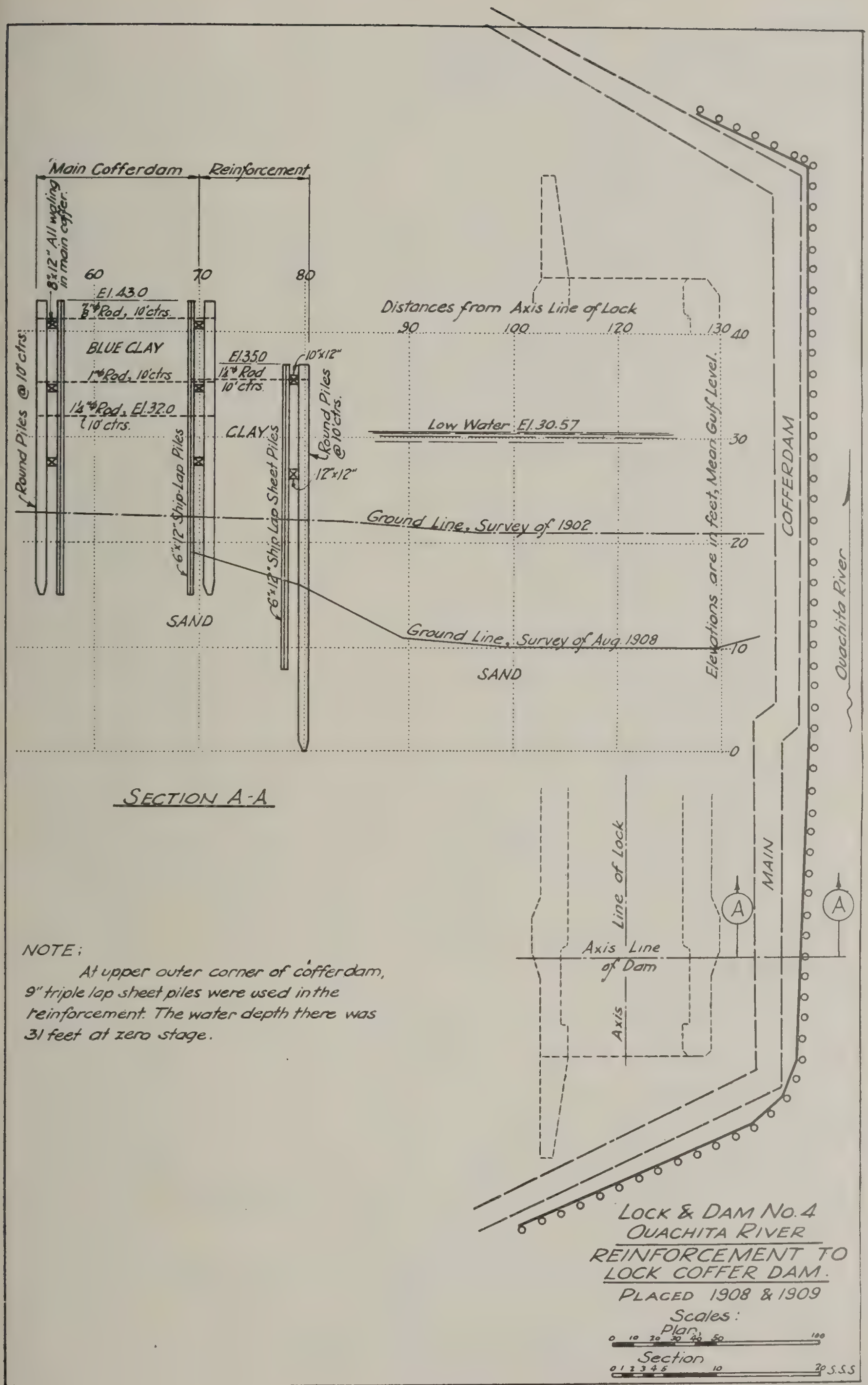

Main Cofferdam
Reinforcement
8"x12" All waling in main coffer.
60
70
80
El. 43.0
7/8" Rod, 10' ctrs.
BLUE CLAY
1" Rod, 10' ctrs.
1¼" Rod, El. 32.0
10' ctrs.
El. 35.0
1¼" Rod
10' ctrs.
10"x12"
Round Piles @ 10' ctrs.
12"x12"
CLAY
6"x12" Ship-Lap Piles
6"x12" Ship Lap Sheet Piles
Round Piles @ 10' ctrs.
Distances from Axis Line of Lock
90
100
120
130
40
30
20
10
0
Low Water El. 30.57
Ground Line, Survey of 1902
Ground Line, Survey of Aug. 1908
SAND
SAND
Elevations are in feet, Mean Gulf Level.
COFFERDAM
MAIN
Ouachita River
SECTION A-A
Line of Lock
Axis Line of Dam
Axis
A
A
NOTE;
At upper outer corner of cofferdam, 9" triple lap sheet piles were used in the reinforcement. The water depth there was 31 feet at zero stage.
LOCK & DAM NO. 4
OUACHITA RIVER
REINFORCEMENT TO LOCK COFFER DAM.
PLACED 1908 & 1909
Scales:
Plan
0 10 20 30 40 50 100
Section
0 1 2 3 4 5 10 20
S.S.S

Fig. 7.

flower Lock, the cofferdam remaining in place during a low water only. At Lock No. 3 on the Ouachita River, the freshet of September, 1913, prevented such a consummation, and the coffer stood during the succeeding high water and through the working season of 1914; at the end of which time it was in an unsafe condition, but the special permanent work described above, while not completed, was advanced to such a stage that only a small portion of the cofferdam would have to be rebuilt. The cofferdam at the Big Sunflower lock, therefore, served the purpose intended; that at Lock No. 3 falling slightly short of that purpose. On the other hand, the former cofferdam was never subjected to any crucial conditions, either of pressure head or scour; while the latter was sensibly weakened by a moderate amount of scour, showed an undesirable permeability, and was saved from failure—by flooding—when the pressure head, reckoned from the bottom of an excavation adjacent to the inner wall, was practically that which it was designed to withstand with safety. The outward list of the Sunflower cofferdam was probably due, in part, to unsymmetrical disposition of the puddle fill, a feature easily corrected; and in part to a displacement of the underlying material, under the shallow footing of the outer wall, a feature intrinsic with the design.

A comparison of these cofferdams, as illustrated on Plates I and II, with the puddle-wall coffers used on the Ouachita River prior to 1913, and illustrated (as to type) by Figs. 7 and 8, indicates that the puddle-wall construction is the stronger and more reliable under adverse conditions; but the experience from 1908 onward indicates that the puddle-wall cofferdams were none too strong, and not always reliable. Following is a review of failures, and near failures, of such cofferdams, 1906 to 1912:

At Lock and Dam No. 4. A puddle-wall cofferdam (No. 3) was built to enclose 60 feet of the navigation pass adjacent to the lock, and was flooded by a blow-under October 19, 1911, at the outer end—the cofferdam not being breached. The head on the cofferdam was about 10 feet when the blow-out occurred. The puddle fill was a sandy clay, about 14 feet thick; walls were shiplap wooden sheet piles with a penetration of about 9 feet, the footing being in fine sand. A failure similar in every respect occurred the same season in a small cofferdam (No. 4) inclosing a part of the drift pass. In each case a concrete seal was deposited subaqueously over the deeper part of the inclosed area, the puddle fill brought back to grade, and the cofferdam then unwatered without further trouble

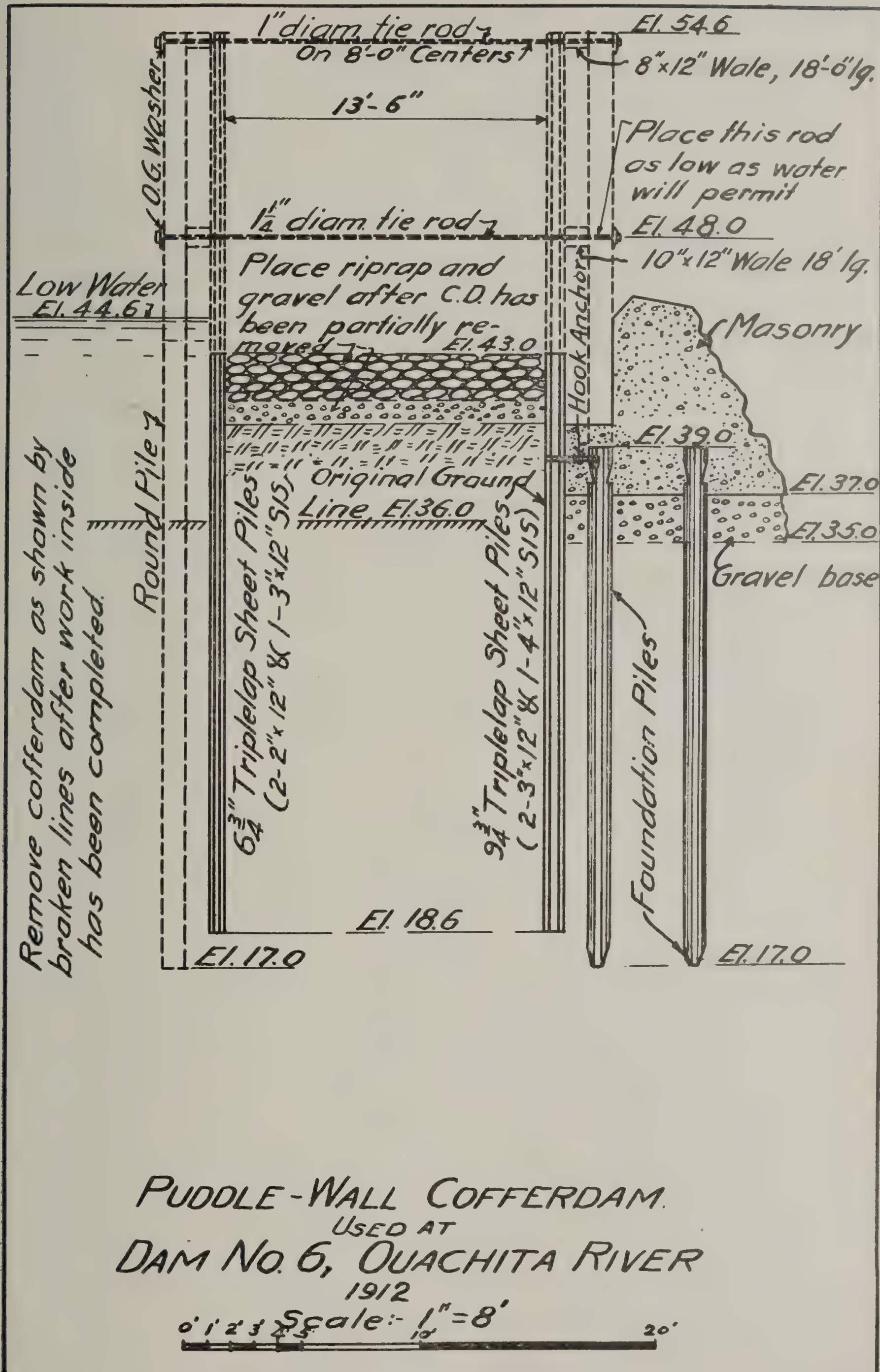

1" diam. tie rod
On 8'-0" Centers
El. 54.6
8"x12" Wale, 18'-0" lg.
13'-6"
O.G. Washer
Place this rod as low as water will permit
1¼" diam. tie rod
El. 48.0
10"x12" Wale 18' lg.
Low Water El. 44.6
Place riprap and gravel after C.D. has been partially removed
El. 43.0
Hook Anchor
Masonry
El. 39.0
El. 37.0
El. 35.0
Gravel base
Original Ground Line El. 36.0
Round Pile
Remove cofferdam as shown by broken lines after work inside has been completed.
6¾" Triplelap Sheet Piles (2-2"x12" & 1-3"x12" S1S)
9¾" Triplelap Sheet Piles (2-3"x12" & 1-4"x12" S1S)
Foundation Piles
El. 18.6
El. 17.0
El. 17.0
PUDDLE-WALL COFFERDAM
USED AT
DAM NO. 6, OUACHITA RIVER
1912
Scale:- 1" = 8'
0' 1' 2' 3' 4' 5' 10' 20'

Fig. 8.

of moment. The above failures were indirectly due to the moderate pile penetration in conjunction with an underlying material that became semi-fluid when saturated.

At Lock No. 6 the lock cofferdam (No. 1) built by the original contractor, was breached January 3, 1911, on the river side, near the upstream end. The head on the dam was 17 feet at the time. The puddle fill was a clayey sand 12 feet thick; walls were of ship-lap wooden sheet piles having an original penetration of 11 feet, which had been reduced to about 9 feet, for the outside wall, by scour. The piles were footed in sand. The structure was similar to that illustrated in Fig. 7. Failure was due to a blow-under.

At Dam No. 6 the cofferdam (No. 2) inclosing the navigation pass was flooded August 29, 1912, at the outstream end, while being unwatered. The head on the structure was 14 feet at the time. The cofferdam was of the puddle-wall type, as illustrated by Fig. 8. The fill was a sandy clay; the walls were composed of triple-lap wooden sheet piles with original penetration of about 18 feet, which had been reduced to about 13 feet along the outer wall, at the time of the flooding, by scour. The piles were footed in sand. The flooding was due to a blow-out of the underlying sand. The puddle fill dropped and closed the opening, and after this fill had been brought back to grade the cofferdam was successfully unwatered.

TABLE I. *Summary of Cofferdam Failures.*

Place.	Date.	Coffer No.	Head.	Pile penetration	Character of—		Cause.
					Puddle fill.	Pile footing.	
			Feet.	*Feet.*			
No. 4	Oct. 19, 1911	3	10	9	Sandy clay	Sand	Blowunder[a]
Do.	Oct. 9, 1911	4	14	7	Sandy clay	Sand	Blowunder[a]
No. 6	Jan. 3, 1911	1	17	9[b] 11	Clayey sand	Sand	Blowunder
Do.	Aug. 29, 1912	2	14	13[b] 18	Clayey sand	Sand	Blowunder[a]

[a]Cofferdam was not breached.

[b]Penetration of sheet piles in outside wall, as reduced by scour.

Cofferdams were damaged by river scour as follows: The puddle-wall cofferdam finally built for Lock No. 4 by the contractor was undermined at the outer upstream corner during the high water of 1906-1907, but the coffer walls were not carried away. A third line of sheet piling was driven around the corner in question and

the space between this line and the outer coffer wall filled with earth. This reinforcement was swept away during the succeeding high water and the river bed scoured to such a depth along the outside of the cofferdam that a reinforcement of practically the entire structure was deemed necessary. In 1908 and 1909 a third coffer wall was built, by hired labor, inclosing about nine-tenths of the original structure, the sheet piles penetrating about 8 feet into the bed of the river (as deepened) and rising about 4 feet above local low water. The puddle fill between the original cofferdam and the reinforcing line averaged 7 feet in thickness. The reinforcement is illustrated by Fig. 7. In the early part of the high-water season of 1909-1910 the upper outer corner of the puddle-wall cofferdam for Lock No. 6 was undermined and 70 feet of the upstream end swept away. Soundings showed that rapid scour was in progress and about 70 feet of the lower end of the cofferdam was removed to permit free flow through that structure and relieve the engorged section. The coffer ends were again removed during the high water of 1910-1911, for the same purpose. The remedy was drastic, but the river section was kept practically intact. During the high-water season of 1910-1911 the upper outer corner of the puddle-wall cofferdam for Lock No. 8 was undermined and a few piles in the outer wall swept out. The pile penetration was about 8 feet into a dense clay. A reinforcement similar to that employed at Lock No. 4 was built around the damaged corner, and a shallow riprap fill placed on the outside.

The change from the puddle wall to the box type of cofferdam was made from motives of economy. It was thought that, with the program of construction finally adopted for the permanent work, a box cofferdam could in the general case be built, serve its purpose, and be dispensed with, in one low-water season; and in the exceptional cases where this could not be done, the box coffer could be replaced, if necessary, at a smaller outlay for the *two* than for *one* puddle-wall cofferdam. In this connection, the following study of comparative costs is of interest.

TABLE II. *Comparative Cost of Cofferdams, Ouachita and Big Sunflower Rivers.*

Classification.	Quantity.	Unit.	Unit cost.	Total cost.
LOCK NO. 3, OUACHITA RIVER (1913-'14), *Box Coffer only.*				
Lumber, wales, sheeting and cross-struts..	93	M. bd. ft.	$62.62	$5,823
Round piles, fender..................	843	Lin. ft...	.25	211
Tie rods with nuts and washers.........	25,369	Lbs. ...	.06	1,522
Puddle fill[1]	7,200	Cu. yds..	.26	1,872
Completed cofferdam, all temporary......	640 7,200	Lin. ft... Cu. yds..	$14.73 1.31	$9,428
LOCK NO. 3, *Box Coffer and Adjacent Sheet-pile Wall.*				
Lumber (sheet piling below final cut-off not charged)	148	M. bd. ft.	$59.44	$8,797
Round piles (guide piles below final cut-off not charged)..................	1,867	Lin. ft...	.25	467
Tie rods, etc.........................	25,360	Lbs. ...	.06	1,522
Puddle fill[1]	7,200	Cu. yds..	.26	1,872
Completed cofferdam, temporary part only	640 7,200	Lin. ft... Cu. yds..	$19.78 1.76	$12,658
BIG SUNFLOWER LOCK, 1914, *Modified Box Cofferdam.*				
Lumber (sheet piling below final cut-off not charged)....................	62	M. bd. ft.	$49.40	$30.62
Round piles (guide piles below final cut-off not charged)..................	1,192	Lin. ft..	.27	321
Tie rods, etc.........................	18,940	Lbs. ...	.07	1,326
Puddle fill[1]	1,820	Cu. yds..	.25	455
Completed cofferdam, temporary part only	427 1,820	Lin. ft... Cu. yds..	$12.10 2.84	$5,164
DAM NO. 4, OUACHITA RIVER, 1911, *Puddle-wall Cofferdam No. 2.* (Inclosing dam abutment and the adjacent retaining wall.)				
Lumber	108	M. bd. ft.	$61.26	$6,616
Round piles	1,975	Lin. ft...	.35	691
Tie rods, nuts, and washers...........	5,317	Lbs.	.05	266
Puddle fill[2]	2,425	Cu. yds..	.66	1,600
Completed cofferdam, all temporary....	290 2,425	Lin. ft... Cu. yds..	$31.63 3.78	$9,173
DAM NO. 6, OUACHITA RIVER, 1912, *Puddle-wall Cofferdam Nos. 2 and 3.*				
Lumber (sheet piling below final cut-off, inner wall not charged)............	260	M. bd. ft.	$62.57	$16,268
Round piles (part below final cut-off, inner wall not charged)............	6,700	Lin. ft...	.59	3,953
Tie rods, nuts, and washers..........	14,450	Lbs. ...	.07	1,012
Puddle fill.........................	7,200	Cu. yds..	.28	2 016
Completed cofferdam, temporary part only	790 7,200	Lin. ft... Cu. yds..	$29.43 3.23	$23,249
LOCK NO. 8, OUACHITA RIVER (1908-'11), *Puddle-wall Cofferdams for Lock* (No. 1) *and Dam* (Nos. 2 and 3).				
Lumber	535	M. bd. ft.	$64.83	$34,681
Round piles	10,771	Lin. ft...	.28	2,944
Tie rods, nuts, and washers...........	52,786	Lbs. ...	.06	3,396
Puddle fill[3]	10,479	Cu. yds..	.47	5,137
Completed cofferdams, all temporary....	1,530 10,479	Lin. ft... Cu. yds..	$30.17 4.41	$46,158

[1]See foot-note to Table III. [2]Barged to cofferdam. [3]Greater part barged to cofferdam.

The above table includes all puddle-wall cofferdams of importance built by hired labor on the Ouachita River. The cofferdams for locks Nos. 2, 4 and 6, on that river, were built by contract, and specific data as to actual cost are not available.

The above covers the field cost of material, supplies and services, no *overhead* is included. The costs of the completed structures are compared both on the basis of unit length and unit volume.

The structures above compared were built under widely different conditions, and it is thought that a fairer comparison of cost can be obtained by assuming cofferdams of the several types, all designed for like heads and like foundations, applying the same unit cost to the same or similar classes of work. Such a comparison is made in Table III below, the conditions for which the cofferdam at Lock No. 3 was designed being taken as a basis. The box cofferdam of Ohio River type (see table) will be that actually built at Lock No. 3, likewise the cofferdam designated as the Ouachita River type. The cofferdam of Sunflower River type will have its inner wall like the triple-lap sheet-pile wall at No. 3, but extended to the top of the coffer; its outer wall like the walls of the box coffer at No. 3; and its tie-rod system like that used at the Big Sunflower lock. The puddle-wall cofferdam will have an inner wall like that of the Sunflower type, waling excepted, and an outer wall of 7-inch triple-lap sheet piling driven to a 12-foot penetration. The waling and tie rod systems of the puddle-wall coffer will be shown on Fig. 8. Sheet piling will be estimated to run 12 piles to 13 linear feet of wall, this being the usual experience on the Ouachita with triple-lap piling.

TABLE III. *Cost of Cofferdam Used at Lock No. 3, Ouachita River, and Estimated Cost of Other Types Designed to Meet Identical Conditions.*
(a) *Actual Cost.*[1]

Classification of work.	Quantity	Unit.	Unit cost	Box cofferdam. Ohio River type.	Box cofferdam. Ouachita River type
Framing—wales, sheeting at panel and half-panel points and cross struts	44	M. bd. ft.	$84.61	$3,723	$3,723
Sheeting not included in framing	49	--do	42.85	2,100	2,100
Wales, guide	7	--do	30.00	------	210
Sheet piles, 10-inch	48	--do	57.60	------	2,764
Round piles, guide	1,024	Lin. ft.	0.25	------	256
Round piles, fender	843	--do	0.25	211	211
Tie rods, nuts and washers	25,360	Lbs.	0.06	1,522	1,522
Puddle fill	7,200	Cu. yds.	0.26	1,872	1,872
Completed cofferdam	7,200	--do	1.31	$9,428	------
Temporary part only			1.76	------	$12,658

(b) *Estimated Cost.*

Classification of work.	Quantity	Unit.	Unit cost.	Box C. D Sunflower River type	Puddle wall C. D.
Framing—wales, sheeting at panel and half-panel points and cross struts	23	M. bd. ft.	$84.61	$1,946	------
Sheeting not included in framing	25	--do	42.85	1,071	------
Wales, guide	7	--do	30.00	210	------
Wales, for puddle-wall coffer	26	--do	30.00	------	780
Sheet piles, 10-inch	84	--do	57.60	4,838	4,838
Sheet piles, 7-inch	128	--do	57.60	------	7,373
Round piles, guide	1,504	Lin. ft.	0.25	376	------
Round piles, fender	843	--do	0.25	211	------
Round piles, for puddle-wall coffer	3,984	--do	0.25	------	996
Tie rods, etc., box coffer	25,360	Lbs.	0.06	1,522	------
Tie-rods, etc., puddle-wall coffer	13,040	--do	0.06	------	782
Puddle fill	7,200	Cu. yds.	0.26	1,872	1,872
Completed cofferdam	7,200	--do	1.67	$12,046	------
Temporary part, only			2.31	------	$16,641

[1]Except that the cofferdam is here assumed to be completely filled (which was not actually done). The unit cost used for the complete fill is that found for the puddle fill actually placed.

The above comparison of costs, both actual and estimated, shows a well-defined difference in favor of the box types, and indicates that a considerable proportion of a given number of such structures could be rebuilt and the total outlay still kept within that required for the same number of puddle-wall cofferdams built to meet the same conditions. However, admitting that more failures are to be expected, *during the working season,* with the box type than with the puddle-wall, there are elements of expenditure not entering into Tables II and III which should be taken into account in making up the final balance. Among these may be listed damage to plant, material, and unfinished structures in the lock pit; probable loss of life, a feature scarcely computable in terms of money, and time lost when time is golden; delays when the iron is hot and the smith at the anvil. More remote, but not fanciful, is the mental attitude of men who know, or believe, that they are working under unsafe conditions; nervous laborers do not rise to the full measure of efficiency. It is true that the box coffer can be built in less time than the corresponding puddle-wall cofferdam and this initial saving might more than counterbalance subsequent losses of time arising from accidents to the former, as far as mere duration is concerned; but the erection of a cofferdam is part of a predetermined program of operations, and the force to be carried while the coffer is under construction is organized in harmony with that work. The experienced construction man will appreciate the difference between extra time provided for in his scheme and unforeseen delays occurring when his full force is employed, in which event he must either sacrifice his organization to a greater or less extent, or carry a number of idle men on his pay-roll.

The box type of cofferdam could be protected from scour by a mattress laid around the outside, at no great increase in cost. A lumber mattress, such as is described in the Chief of Engineers' report for 1901, pages 2212 to 2220, could be built for the cofferdams considered in Table III at an estimated increase of 10 cents per cubic yard of volume in the cost of construction. The lumber mattress described in PROFESSIONAL MEMOIRS (No. 39, p. 383), would cost less. The Ouachita River being subject to freshets during the low water seasons, such a mattress would be a valuable safeguard for box cofferdams on that stream, even though it was not anticipated that the coffer would be required to stand through a high water season.

The weakness due to scour being eliminated, there remain the

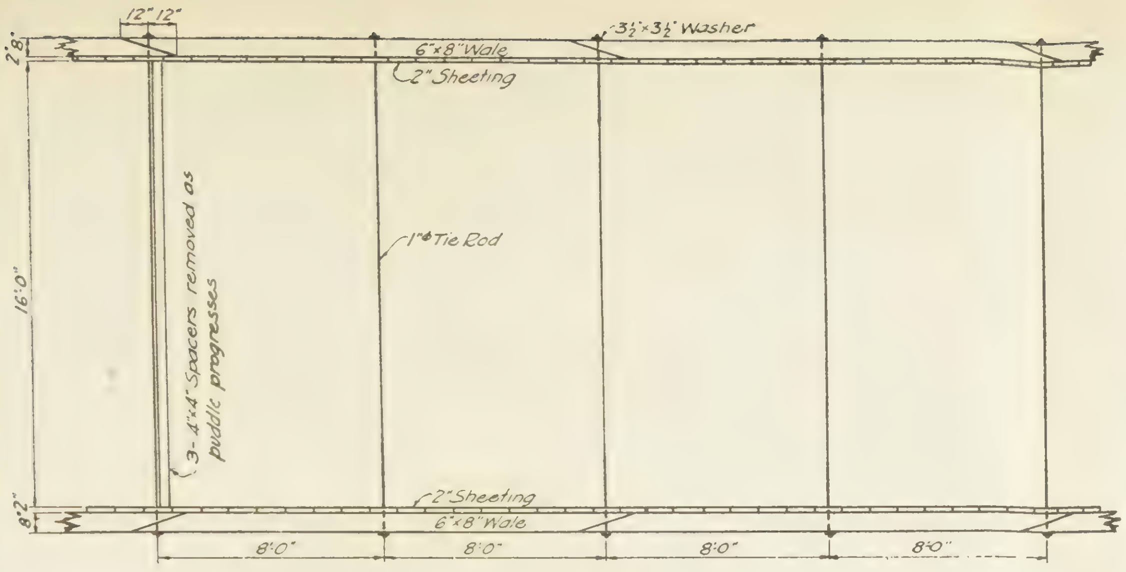
questions of stability and permeability. Box cofferdams of the Ouachita River and Sunflower River types can be given a stability equal to that of the corresponding puddle-wall cofferdam by providing a relatively wider section for the former—a feature readily provided for, but at the expense of an increase in the puddle fill and metal. The permeability of the Ouachita type of coffer can probably be reduced to that of the Sunflower type by building the *box* as close as practicable to the sheet-pile wall and puddling the intervening space *with care;* but the percolation resistance of both types is intrinsically less than that of the puddle-wall cofferdam on account of the meager penetration of the sheeting in one wall; a characteristic feature of the box types, to depart from which would involve changing to puddle-wall construction.

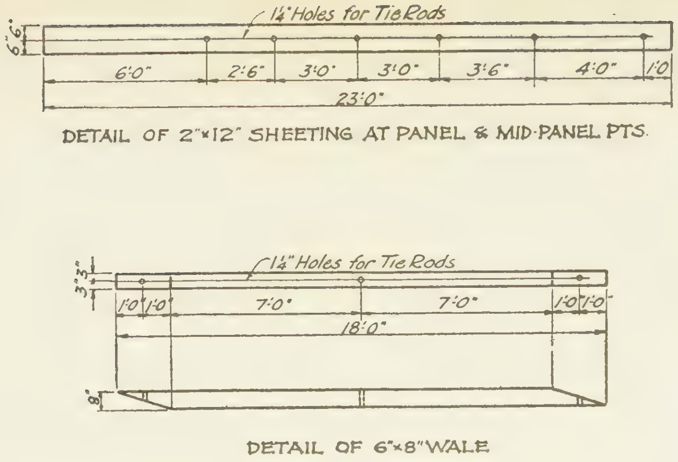
It is concluded that *box* cofferdams of either the Ouachita or Sunflower type, of moderate height—say, not exceeding 12 feet—with a puddle thickness equal to the height, protected from scour, and with all deep foundation work adjacent to the inner wall executed in cross-braced trenches, can be employed with confidence. The use of these types of height approximating that of the cofferdam at Lock No. 3, is thought to involve risks that should not be taken.

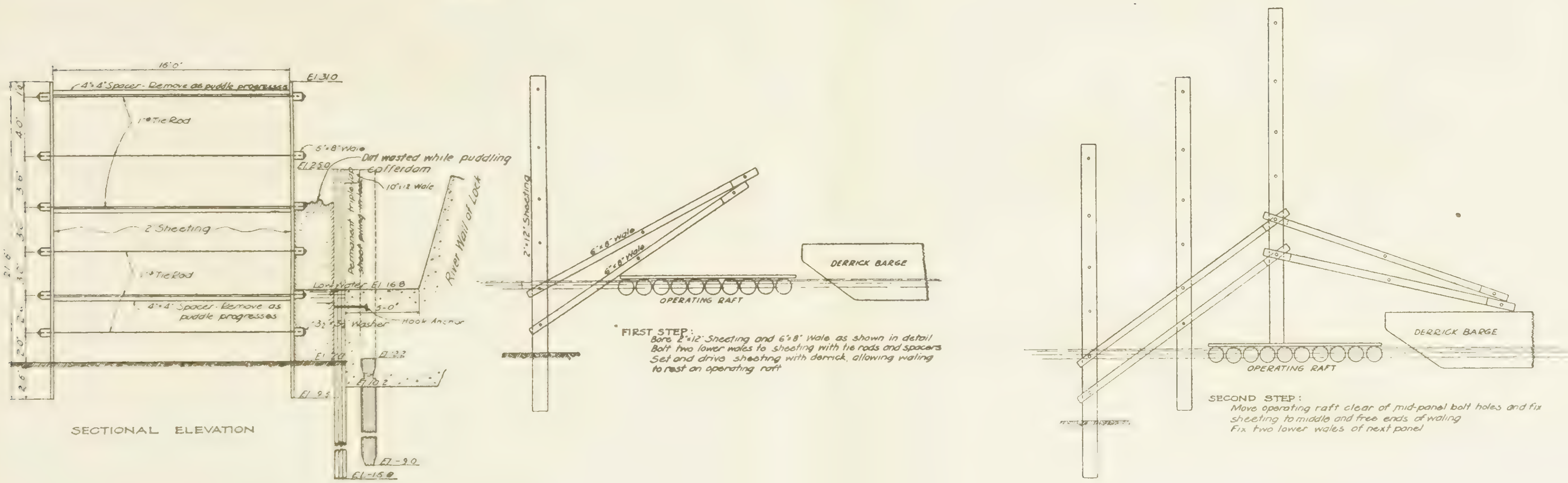
COMMENTS *by* MAJ. H. C. FISKE, *Corps of Engineers; District Engineer Officer.*

The Ouachita River flows through an alluvial plain where equilibrium has been attained between the force of the flowing water and the resistance of the material of the bed and banks. This means that though banks will slough and minor cut-offs will occur from time to time, the channel, the bars and the banks have not changed enough to affect navigation in historic times. This general stability was rightly considered to be sufficient to justify the building of a system of locks and dams, but experience has shown that one feature which in the usual stable river is of minor or secondary importance becomes here the governing consideration.

At the outset it was assumed that the river bed, whose cross section was not subject to marked changes, was sufficiently stable to hold its form during the construction period, but the error of this assumption was soon apparent. In his article, Mr. Thomas tells briefly how the small increase in velocity and direction of the currents caused by the cofferdams, even at the lower stages, started scouring of the bed which was sufficient to cause the distortion and even destruction of these structures, until special precaution had been taken to protect them. In some instances between the coffer and the farther bank the bed was scoured so deep that part had to be refilled at considerable expense and the foundations of the rest







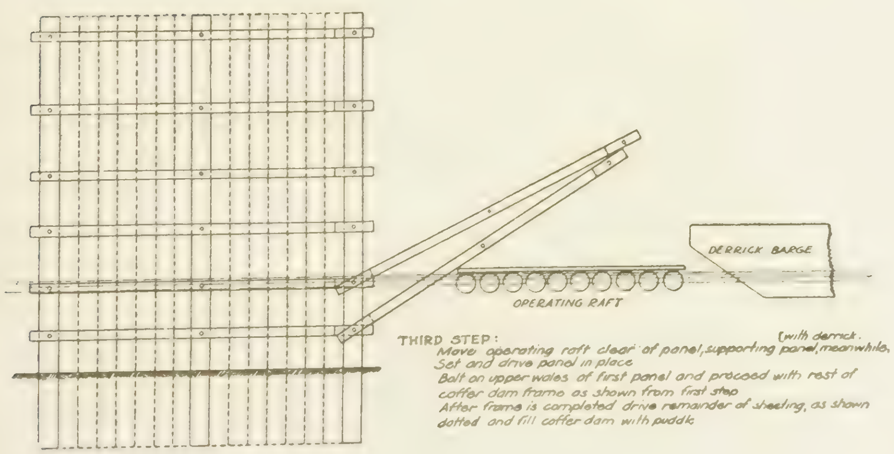
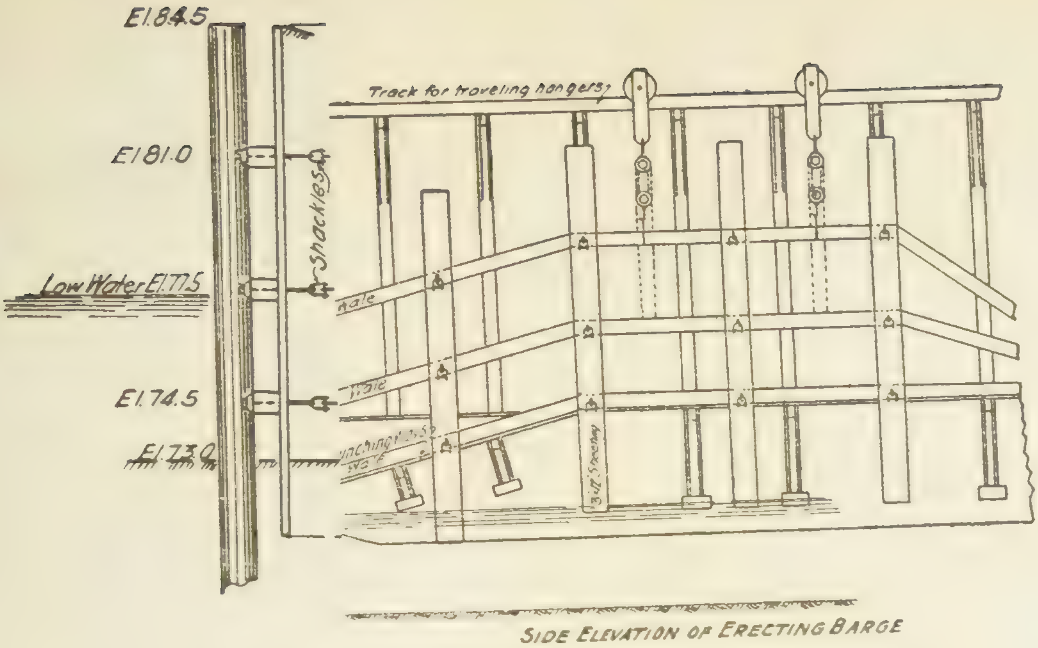


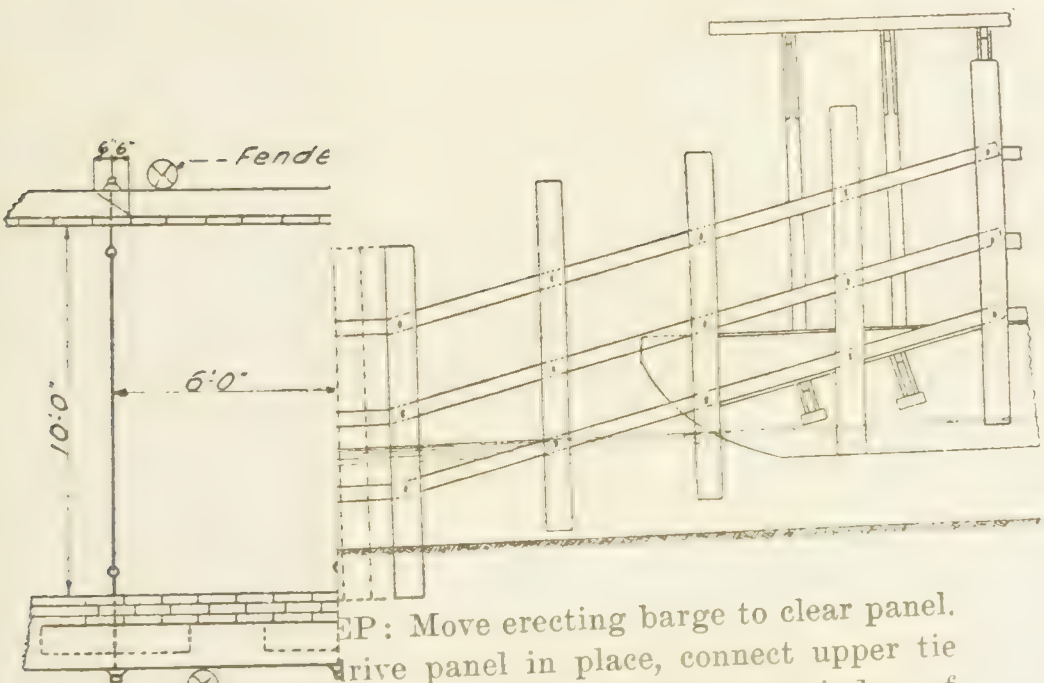
Plate I.

Improving Ouachita River, Louisiana,
Lock and Dam No. 3.
Box Cofferdam, as Built in 1913.

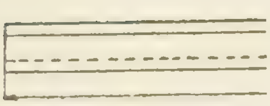


ls in each sixth pile, when 1¼-inch
ıg wale in place with eye-bolt at-

SECTIO



EP: Move erecting barge to clear panel.
drive panel in place, connect upper tie
er panel is set, drive remainder of
as shown dotted, and fill cofferdam
dle.

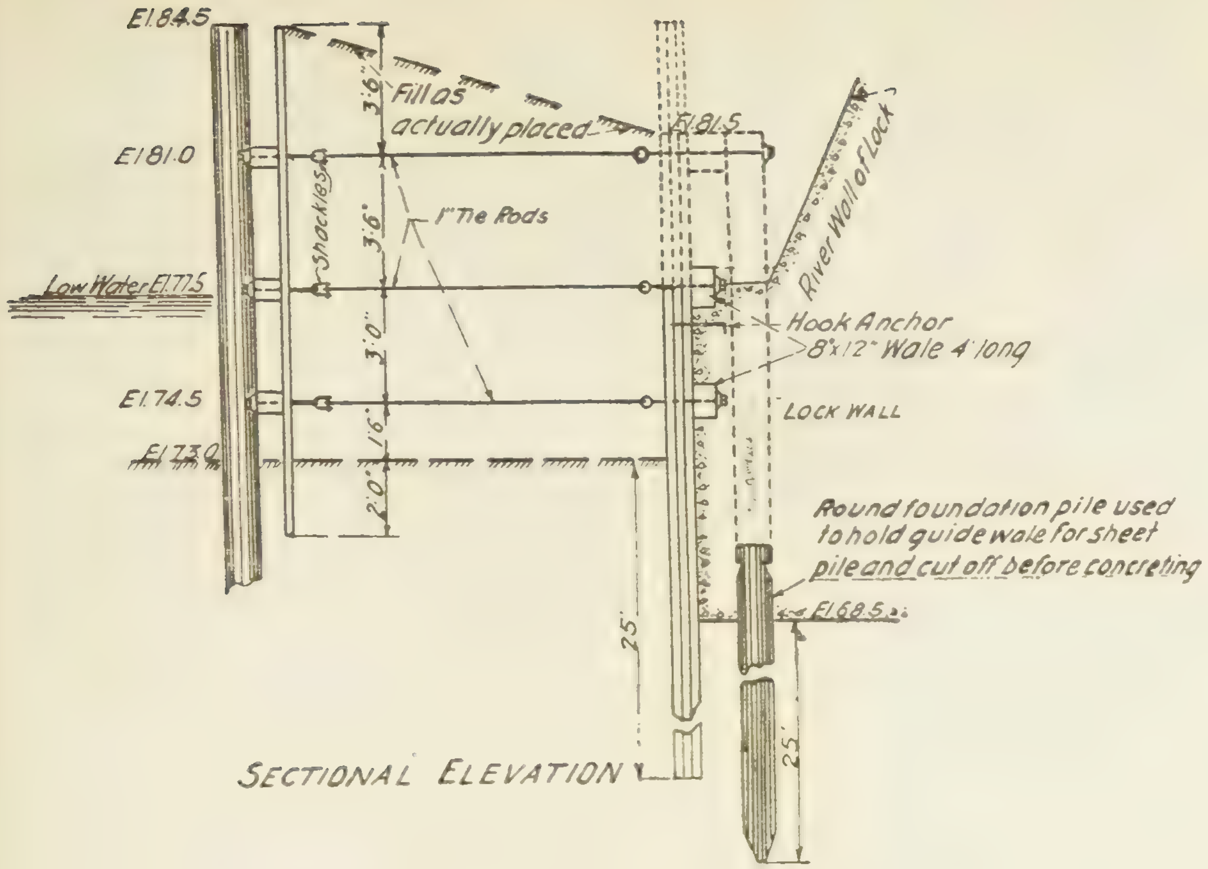


DETAIL O

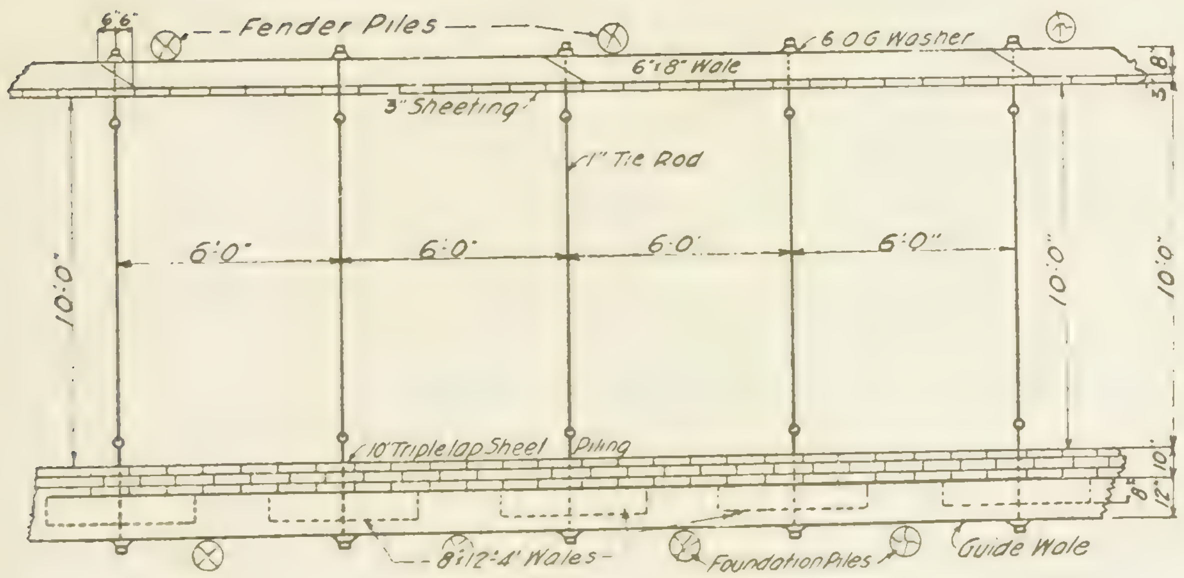
Plate II.

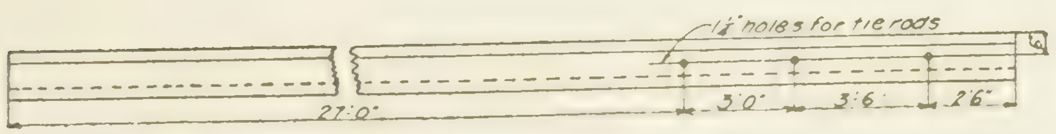
DETAIL OF

Big Sunflower River, Mississippi.
flower River Lock and Dam.
ofterdam, as Built in 1914.

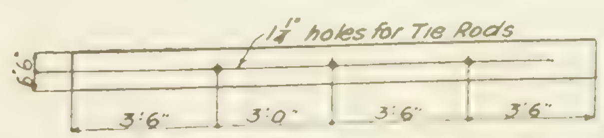


SECTIONAL ELEVATION

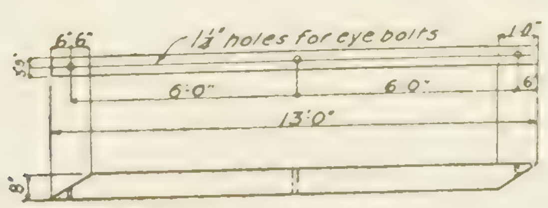




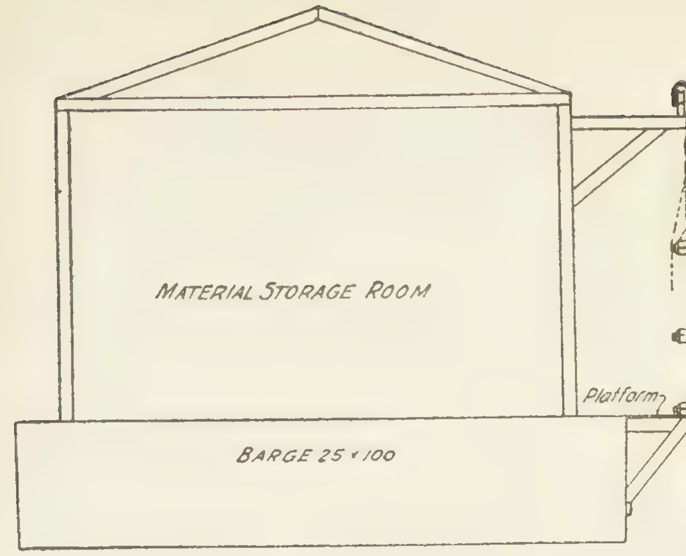
DETAIL OF 10" TRIPLE-LAP SHEET PILE



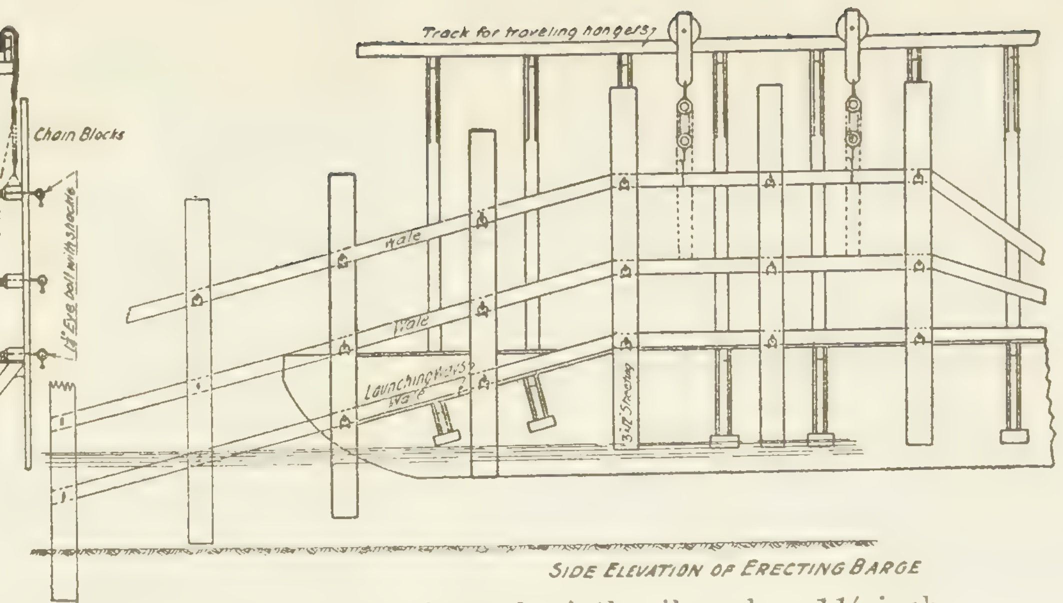
DETAIL OF 2"x12" SHEETING AT PANEL & MID-PANEL PTS



DETAIL OF 6"x8" WALE



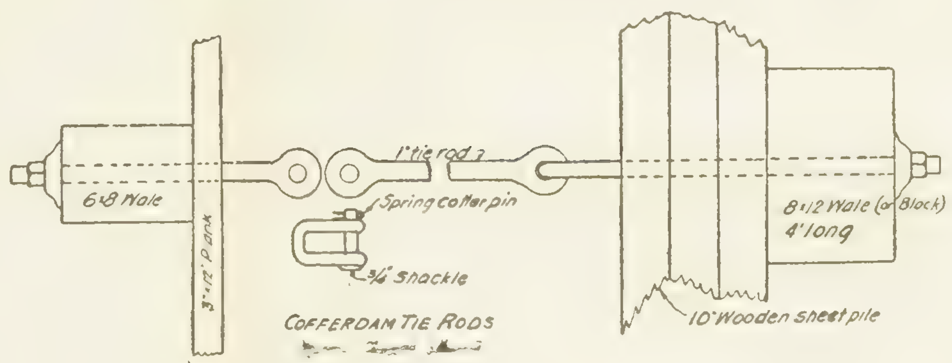
END ELEVATION OF ERECTING BARGE



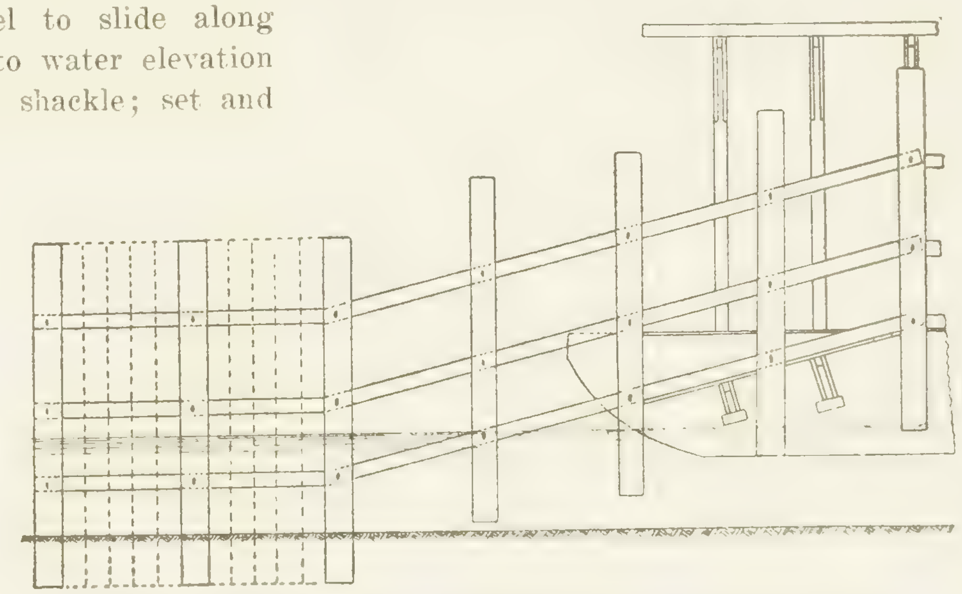
SIDE ELEVATION OF ERECTING BARGE

FIRST STEP: In driving triple-lap sheet piles, place tie rods in each sixth pile, when 1¼-inch hole passes guide wale place 8 by 12-inch 4-foot wale, holding wale in place with eye-bolt attached to tie rod.

SECOND STEP: Erect panels on platform of erecting barge, by bolting wales to sheeting with eye-bolts, with shackle attached, then move barge, allowing panel to slide along launching ways; when bottom wale gets to water elevation attach tie rod of sheet pile to panel with shackle; set and drive 3 by 12 sheeting in place.



COFFERDAM TIE RODS



THIRD STEP: Move erecting barge to clear panel. Set and drive panel in place, connect upper tie rod. After panel is set, drive remainder of sheeting, as shown dotted, and fill cofferdam with puddle.

Plate II.

Improving Big Sunflower River, Mississippi.
Big Sunflower River Lock and Dam.
Box Cofferdam, as Built in 1914.

of the structure had to be increased in depth and cost. To protect the coffer it has been found necessary to build it with one wall of sheet piling or to build it very close to such a line of piling which forms part of the permanent structure. To prevent scour in the open river it has been found necessary to make the coffer as small and unobstructive as possible. Experience on the Big Sunflower River (where conditions are much the same as on the Ouachita) has shown that where work can be completed and the coffer removed in one working season, entirely satisfactory results can be obtained with coffers which follow the above-mentioned requirement. On the other hand, it is considered certain that had an attempt been made to carry this coffer through a high water season the scour in the open river would have verged on the disastrous and the coffer itself would have been lost.

This year the dam at No. 3, Ouachita River, is to be built. It is fairly certain that one-half of the dam can be completed, but the second half may have to wait until the next season. The problem is, in this event, to leave the structure in such shape that no scour will occur which might injure either the incomplete concrete base or the adjacent river bed. Of several methods suggested, the following seems to promise the best results and will be adopted. The line of steel sheet piling for the dam has been driven from the abutment to the lock wall. As the coffer for the section of the dam adjacent to the lock wall is built the timber crib for the other section of the dam will be built out from the abutment to meet this cofferdam. Below the crib there will be left a strip of natural river bed on which the second coffer can be built and below this the permanent riprap will be placed. Scour in the open river will then be impeded by, *first*, a row of steel sheet piling; *second*, a rock-filled timber crib and, *third*, an apron of riprap 35 feet wide. It is not expected that any serious scour will occur in the two open strips, in one of which the round foundation piles will have been driven. These strips will be watched and if necessary they can be covered with riprap. The coffer will be of the type described by Mr. Thomas, the modified box, with one wall of sheet piling and the outer corners protected by deep driven sheet piling.

It should be emphasized that in Table III the Ohio River type of cofferdam used in this comparison is assumed to have exactly the same length as each of the other three types. These other three types are built with the inner wall either in contact with the permanent construction inside or very close to it. On the Ohio River the Ohio River type is always built with 25 feet or more clearance between its inner wall and he permanent work inside. In addition, it is usually banked on the outside and frequently on the inside. In order, then, to give the same area of working space, the Ohio type would have to be made at least 100 feet longer than either of the three and this additional length would bring the total cost up to $10,900. The necessary banking would probably bring the cost up to at least as much as that of the Ouachita or Sunflower River types. Moreover, for the same working area the Ohio type would be too obstructive to the current of these particular streams.

Professor Dennis Hart Mahan.

BY

Maj. F. A. MAHAN,
U. S. Army, retired.

Professor Mahan was born in the city of New York very shortly after the arrival of his parents from Ireland. The family soon moved to Norfolk, Va., where my father's life was passed until he went to Richmond, there to enter the office of Dr. Archer with the intention of studying medicine. So far as known, he had no leaning toward a military life, but he was anxious to learn to draw, a desire which could not then be gratified in the South; so, having heard that drawing was taught at the Military Academy, he obtained an appointment as cadet from the Hon. Isaac Newton, M. C., whose son, John Newton, became later one of the most distinguished officers, as well as Chief, of the Corps of Engineers.

The future professor arrived at West Point on July 4, 1820. There is little to be said about his cadet life except that, almost from the beginning, he attracted the attention of the then Superintendent, Major Thayer, and that he was detailed as instructor in mathematics while still only in the third class, and remained such until he was graduated at the head of his class on July 1, 1824. He was assigned to the Corps of Engineers and was detailed for duty in the Department of Mathematics, where he remained from August 29, 1824, to August 31, 1825. For five years he was disassociated from the Academy, spending four years of this time on special duty in France. He followed for one year the courses of the School of Artillery and Engineering, then and until 1870 at Metz. The remaining years were spent in studying public works, military institutions, methods of instruction and in purchasing many articles in the way of technical apparatus needed at the Academy. His life's work was begun with his appointment, on September 1, 1830, as acting professor of Engineering. He became professor on January 1, 1832, and remained such until his death, having been the head of this department for forty-one years.

From the time of his appointment as acting professor, the Military Academy was my father's life. He earned there a most distinguished reputation, and when the National Academy of Sciences was founded in 1863 he was one of the fifty original members.

It is rather curious that he should have had no bias toward the profession of arms, for few men have ever possessed such strict and lofty military ideals. He was a soldier to the core, but he cared little for the pride, pomp, and circumstance of arms.

The work of the teacher, however important and absorbing in itself it may be, does not offer much of interest to outsiders but, by virtue of his position, he had known and weighed well nearly every one of the distinguished generals of our great civil war, whether on the Union or the Confederate side, as, almost without exception, they had been his pupils.

General King gives in his book, "The True Ulysses S. Grant," the following sketch of my father, upon whom it fell, as the last of the professors of the mathematical sciences, to give to the cadets of the first class their introduction to subjects which would bear more or less strongly on the practical side of their profession in the future:

> Keen, incisive, often satirical, sometimes sarcastic, his daily rasping stung the mental skin to vehement action—a recitation in that awesome presence was an intellectual needle bath of ice water, swift followed by a swifter rub with a steel wire towel. The cadet who came before Mahan with merely a superficial knowledge of the subject inevitably found himself in pitiable plight. There never was a quicker eye or sharper tongue for shams of any kind. Unerringly and almost instantly he could discover just how much a pupil knew on any point, and then if that pupil were not humility personified it was rich to hear Mahan dissect him. No cadet, from the head of the class down to the foot, was safe from his sarcasm or proof against his prodding. They feared him as they admired him. They gloried in his teaching as one does in a desperate battle—after it is over. There was just one quality in a pupil which he apostrophized again and again as indispensable to the would-be commander of fighting men. Without it, brilliancy, knowledge, book learning, study, strategy and tactics, all combined, were of little worth. "Common sense," said Mahan, "was worth them all, and was the one quality without which no man could hope to win." This he held as a theory prior to the great war of the sixties; this he triumphantly declared, as a result of observation of all its leaders, a proved and petrified fact; and this he emphasized in his lecture room in May, 1866, to the very last class graduated under the auspices of the Corps of Engineers.

This description of my father in the section room was true

from the cadet point of view. Intensely conscientious himself, he could not brook from any one under him the slightest laxity in matters of duty. Every effort had to be put forth to accomplish the end sought, and any failure of effort, any trifling with work, was sure to call forth my father's wrath. But for the earnest worker, the man who at all times was doing his best, there was always a warm feeling of appreciation. Father never praised work well done; it was a man's duty to do his work to the best of his ability and the acceptance of his work by his own conscience was the worker's true reward.

In his teaching, my father devoted himself much more to principles than to the working out of details. He used to say: "If a man understand his principles thoroughly, he will find little trouble in their application." This does not mean that the mode of applying the principles taught was set aside; there was enough of application of principles to make the use of the latter perfectly clear.

As a teacher, he had the rare faculty of imparting much instruction in few words. A very clear thinker, he found always just the right words for conveying his ideas, and his definitions were short and precise. In the section room, he required that exact answers should be given to exact questions, and nothing annoyed him more than to have time wasted in an endeavor to define a thing which was not clear in the mind of the cadet who was reciting. No beating about the bush was ever tolerated, and it were far better that the answer, "I do not know, sir," were made than that time were wasted in idle words. I was one of my father's assistants for a year. One morning, a member of the section, who "was up on questions" during the last few minutes of the recitation hour, showed an unusual faculty in evading the answers to the questions put to him. When the section was dismissed, father turned to me with a laugh and said: "As you go through life, just notice how almost impossible it is to obtain a direct answer to a direct question."

In these days we hear so much of practical men in contradistinction to theorists, and when slang is so rife among all classes, I can not help mentioning a couple of points which were given to me by my father, who was a purist in the matter of English.

One afternoon, while we were walking together, I said to him that I did not care much for theory; that I wished to be a practical man. His answer was: "My boy, remember one thing, the only

really practical man is the one who is thoroughly grounded in his theory."

While I was on duty at the Academy, my father desired me to take my meals with the family instead of at the mess. I chanced to use at dinner one day some bit of slang, which caused him to say that he wished that I would give up "that abominable habit of using slang." I, naturally, tried to defend the slang on the ground that sometimes one could express oneself more strongly by the use of slang than in the vernacular. This called forth the withering retort, "That merely shows your ignorance of the language."

A remark which he made to my class, at the close of the course in the Art of War and the last time we came before him prior to our graduating examination, has never been forgotten by one member of the class, at least. "Young gentlemen," he said, "you have now finished your course at the Military Academy, and most of you think, no doubt, that you know all that is to be learned; but let me add one last word: I have been all my life a harder student than any one of you, but I never enter that library" (pointing in its direction) "and see the sum of human knowledge contained therein without feeling ashamed to think how little I know."

As my father's early life had all been in the South, his sympathies, when the Civil War broke out, were with the old friends for whom he could not help feeling sad; but his heart and his honor were for the Union, and his best friend in assailing that became his enemy. More than one army officer from the South was kept by him loyal to the Union and the Flag. He said to my brother—the late Admiral Mahan—on one occasion: "I did not think that I could ever again be happy should our country fall into her present state, but now I am so absorbed in seeing those fellows beaten that I lose sight of the rest." He loved his country; while distinctly opposed to much for which the North then stood, he took his stand on that side because the North upheld the Union.

My father, within the limits of human nature, was an absolutely just man. His mind was distinctly judicial in character. He never judged until he had studied every side with care, and his clear, analytical mind quickly found what was essential and discarded what was not germane. Hard, stern, and uncompromising in all matters of duty, standing always on the ground that whatever was not distinctly and wholly right was wholly and distinctly wrong, admitting no tampering with principle, no man

was more ready to listen to the other side or to admit wrong on his own.

But no man could blaze with anger more fierce than his when a wrong was done and, without regard for the harm he might do himself, he would try his utmost to have the wrong repaired; nor did he ever hesitate to protect another where trouble from the discharge of duty might result to the latter. My brother relates the following incident:

> Shortly after father's death, I met a contemporary and military intimate of his. "I want," he said, "to tell you an anecdote of your father. We were associated on a board, one of the members of which had proposed, as his own suggestion, a measure which I thought fundamentally and dangerously erroneous. I prepared a paper contesting the project and took it to your father. He read it carefully and replied: 'I agree with you entirely; but ——— will never forgive you, and he is persistent and unrelenting to those who thwart him. You will make a life-long and powerful enemy. If I were you, I should not lay this upon myself.' I gave way to his judgment and kept back the paper, but you may imagine my surprise when at the next meeting he took upon himself the burden which he had advised me to shun. He made an argument substantially on my lines and procured the rejection of the proposition. The result was a hostility which ceased only with his life, but between which and me he had interposed."

The incident was characteristic of the man.

While I was a cadet, he would never be present at my examinations, always leaving the hall when my name was called. As a first classman and in his own department I received, perhaps, less mercy than others; but I was his son and there must be no idea of favoritism in the hearts of others. My father never ceased to obtain from his assistants what their impressions about me were, but never would he say a word in regard to my marks or my standing; these he left to his assistants: Benyaurd, Twining, and Michie, three honors to our Corps, under whom I successively came.

For those in trouble or in doubt, my father was sympathetic and most kind and many an officer of the old army can recall, I doubt not, a word from him which was an influence for good on his life.

The Work of the Royal Engineers in the Field.[1]

BY

Lieut. C. G. MARTIN, V.C., D. S. O., R. E.

The title of the lecture embraces such a wide range of subjects that perhaps it would have been better if I had placed the word "Some" before it, as "Some of the work of the R. E. in the Field" would probably have been a more suitable title. For it is obviously impossible to give even the most sketchy account of all the different branches of R. E. work in this war.

So I have been compelled to neglect several most important branches of our work, to touch lightly on others, and to enter into details of one or two only. My choice has been made firstly in those in which I have had personal experience at the Front; secondly, in those on whose work I have been able to obtain first-hand information, and finally in those which are thought to be of most general interest to you.

I am afraid I have nothing to say this afternoon which would be of use to Artillery Officers from a technical point of view, except emphasizing the importance of all branches of our army having a general knowledge of the work of other branches. In your Corps many officers hold, or will hold, certain Staff appointments in which the employment of the R. E. plays an important point, and to such I hope this lecture may be of use in helping them to arrive at the best solution of that always much debated problem—"The most efficient method of employing the Royal Engineers in the Field."

Many of the old ideas on the legitimate work of the R. E. in the Field have now become obsolete, and when I come to deal with the work of the R. E. Field Companies I hope to be able to show how the new conditions of warfare have brought out new ideas, and how these ideas are best applied.

It will be interesting to consider for a moment the organization of the R. E. before war was declared, as we can then see where this organization failed under the new conditions of trench-warfare and

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[1]A lecture delivered at the Royal Artillery Institution, Woolwich, April 6, 1916. Reprinted, by courtesy of the *Royal Artillery Institution*, from *The Journal of the Royal Artillery* for July, 1916. The entire lecture is reprinted, except as to introductory and closing remarks.

what changes were necessary to enable it to meet and overcome these conditions.

The R. E. with the original British Expeditionary Force were divided into two classes:

1. Divisional Engineers, under which was allotted for each Division—

    2 Field Companies and
    1 Signal Company.

2. Engineer Units on Lines of Communication, comprising

    Fortress Companies,
    Works Company,
    Railway Company,
    Signal Companies,
    Printing Company.

I propose to run shortly through the work done by some of these units.

The *Works Company* was intended for work at the Base, but owing to our numerous Bases it was split up into Sections—one being at each Base.

Assisted by French civilian-labor contractors and working parties from any infantry available, they were responsible for the complete erection of the Base Camps, and *all* work in connection with them such as Water Supply, Drainage, Lighting, Sanitary Arrangements, and Road Making.

They had also, at the same time, to provide Store accommodation for the large quantity of supplies and Ordnance Stores which were arriving, the work for the most part being adapting existing buildings and sheds to meet the requirements of those concerned—sometimes very difficult work.

Their function at present is mainly the upkeep of the Base Camps which are now run more or less on the lines of any town at Home having its own organized Engineer Staff.

I will show you an example of the work of these Units on the lantern at the end of the lecture.

The *Fortress Companies* did not come into active use until the Aisne, and from that time their work was essentially connected with that of the Field Companies. When the New Armies were formed Army Troop Companies took the place of the Fortress Companies, and the latter name is no longer used.

These *Army Troop Companies* can be placed at the disposal of the Chief Engineers of the different Corps, and their rôle is to assist the Field Companies in the construction of the defensive lines. They have been employed for the greater part on the second line trenches and strong points.

The Signal Service may be roughly divided into two parts; first, communications in rear of Division Headquarters, and second, those in advance of Division Headquarters.

In rear of the various Division Headquarters the majority of lines are of a semi-permanent nature, and the system is not unlike that employed in Post Offices. All the instruments used are similar to those in use in post offices at home. At the Headquarters of Armies, and at the Bases, high power instruments are being employed, such as the Wheatstone Automatic, which can send telegrams at speed of from 200 to 600 words per minute.

In advance of Division Headquarters a very highly trained personnel is required, as great mobility is essential. Cable can be laid from a cable wagon with horses going at a hard canter, and can be picked up at the same pace. During the retreat from Mons, communication during the day was almost entirely by motor cyclist, but as soon as units went into billets, cables were laid from Division Headquarters to Brigades each night, and again from Brigade Headquarters to Battalions. This cable was picked up again before moving off each morning (usually about 3 a. m.) and I know of one Division which only lost 5 miles of cable in the whole of the retreat.

About six years ago, the whole of the Signal Service was reorganized, and when the war broke out it was hardly out of the experimental stage. The enormous importance of good communication has been recognized by all Commands, and the personnel of the Companies has been considerably augmented since the beginning of the war. The use of telephones for conversation between actual commanders was found almost indispensable, although early in the war practically all work was done by telegraph only. At the present time within a Division there is a duplicate set of lines so that telegraphy and telephony are kept quite distinct. Each Divison has its own telephone exchanges, and at a Division Headquarters there may be as many as twenty different lines to one exchange.

The greatest test to which the communications within a Division are put is in the Attack, and several alternate lines are always laid to ensure perfect communication.

We now come to the *Field Companies*, with whose work I am mainly going to deal this afternoon. The brunt of the Engineering Work in this war has fallen on these units, and the work accomplished by them includes almost every branch of engineering.

I should like to run briefly through the work performed by the Field Companies in the early part of the war, up to the end of October, 1914, when trench warfare commenced.

I think the easiest way to deal with the subject is to follow the movements of our troops, and see what engineering work was carried out during the retreat from Mons and the advance to the Aisne

At Mons on Saturday August 22nd, and the next morning, the R. E. had their first experience of assisting the infantry in the preparation of a position for defence. The R. E. work consisted of giving advice as to the siting of trenches and then putting any special points such as a farm, or small village, into a state of de-

fence. The shortage of tools was very noticeable at this period, and much time was spent in collecting all available types of shovels and spades from the neighboring district.

Late in the morning, on Sunday, an order came to the C. R. E. that the bridges over the Mons Canal had to be demolished. Eight sections, consisting of a Subaltern, 20 men and 1 tool cart set out for the bridges as fast as possible. Unfortunately, the distance to the bridges varied, those close at hand were successfully destroyed, those at a distance were in the hands of the Germans when the R. E. arrived, but at the intermediate bridges the Germans arrived when the Sappers were at work—two sections were missing, one being entirely wiped out.

This brings up a most important point, and that is, everyone must grasp the fact that R. E. work takes time. To demolish a bridge is not the work of a minute, but may take three or four hours, the time depending on the construction of the bridge. Until this fact is realized orders will still come in at the last moment which, if a successful result is to be attained, should have arrived two or three hours earlier.

Turning from engineering work for a moment, we come to a very different rôle sometimes played by the R. E.—that is, Infantry work.

On one occasion most of the Sappers were put into the firing line alongside the Infantry, and many instances of the same kind occur from time to time.

This, again, brings up another important point. Is it worth while using up your Sappers as Infantry? The answer is unquestionably "No," for it is absolutely essential to have the Sappers available *after* the fight to assist in consolidating the new positions taken up. Of course there are occasions where, in the last resort, the R. E. had to be called upon to act as Infantry, but it should only be done as a last extremity, and then only under orders from the Divisional Commander.

When the advance commenced, the nature of the R. E. work changed. From "destruction" we now turned to "construction"—Engineer reconnaissance of roads—river crossings—demolished bridges—and fortified positions formed the bulk of the R. E. work, and when the Aisne was reached, the Sappers had their first opportunity of bridging on a large scale.

The River Aisne had a mean width of about 170 feet, and a depth of about 15 feet. Five permanent bridges which had been demolished were at once made passable for infantry in single file, and later repaired to take mechanical transport.

I will show you, on the lantern at the end of the lecture, some examples of bridge repairs performed by the Field Companies.

When one reads of bridge building, ones thoughts at once go to pontoons, girders, and other types of bridging; but from the Sapper's point of view the actual construction of the bridge is the simplest portion of the task—the real hard work beginning when the approaches are commenced.

To make a satisfactory approach to one of the bridges over the Aisne, a road of about 200 yards in length had to be made. This necessitated collecting brushwood for the construction of over 2,000 fascines, their transport to the site of the bridge, and the collection of all available road metal in the neighborhood.

During this short period one great defect in our organization—a defect which the Corps had long recognized and which they had endeavored to rectify without success—became so apparent that in October the necessary change was made and a 3rd Field Company added to the Divisional Engineers.

Up to this time the Two Field Companies had to distribute themselves between three Brigades. The closest cooperation between the O. C. Field Company and the Brigadier—which is essential if the work of the R. E. is to be in any way successful—was impossible when the companies were split up between the brigades.

Much time was wasted on the road moving from one part of the Division to another, and,—a smaller matter, though equally important—great difficulty was experienced in obtaining supplies, as they were invariably sent to the Brigade we had just left.

On the introduction of this 3rd Company, the work went most smoothly. Each Company was attached to one Brigade, but under the orders of the C. R. E. Division and Divisional Commanders. This is a most important point, for it is essential that the R. E. should be available for work only where they are needed most, and therefore the control being with the Divisonal Commander, if necessary all the Companies can be concentrated with one Brigade, or on one piece of work.

Now the 3rd Company simplifies to a great extent the difficulty of cooperation between the O. C. Field Company and the Brigadier. Under ordinary circumstances the Field Company should work, as far as possible, with one Brigade, and by so doing officers and men get to know each others ideas. Nothing makes R. E. work more difficult than when lack of cooperation exists, and where orders are drawn up and then submitted to the R. E. for advice in place of the R. E. advice being obtained before the orders are written. As the R. E. work now is the foundation on which all schemes are built, it is disaster to try and carry out cooperation without having first consulted and examined the R. E. conditions.

In the same way, cooperation is essential between the Divisional Staff and the C. R. E., for in the type of warfare we are now waging, success or failure of any operation depends, to a great extent, on the care with which the Engineer details have been worked out.

Now I propose to come to the time when Trench Warfare was commencing, and to consider the position of those R. E. Units which took part in it, and to show what they were asked to do, how much they were actually able to do, and how they overcame the immense amount of work with which they were asked to deal.

It would be as well just to remind you of the composition and

strength of a Field Company as, from the demands made on us in the earlier stages of trench warfare, one would imagine we had an unlimited supply of men who never needed rest, of tools which never needed repairs or sharpening, and of material which never needed collecting.

A Field Company, from a working party point of view, consists of four sections, each under a subaltern; each section being able, at full strength, to supply a working party of 30 men, but which under average conditions rarely exceeded 20.

Thus, supposing the Company was attached to work with a Brigade, each Battalion of that Brigade if in need of R. E. assistance would be able to have 1 Subaltern and about 20 men.

I will briefly mention the different calls which may be made on the R. E. during trench warfare:

Site and mark out Fire trench;
Distribute tools, and place the men at the tasks;
Supervise construction;
Make traverses;
Lay out wire along front of trench, say, 300 yards;
Dig communication trenches back;
Make Machine-Gun Emplacements in front trenches;
Construct dug-outs for officers and men;
Revet trenches;
Make loopholes;
Arrange drainage;
Repair all damage, and daily wear and tear;
Collect material for all the above.

We got the same calls for the Support Line, and also for the Reserve Line.

The Brigade had, at the same time, the following calls on the Field Company, consisting of the four sections working as above:

Make strong points near Reserve Line;

The Division also had calls on its three Companies to—

Construct the Second Line the same as for First Line.

The Corps had its calls on the Divisional R. E. to—

Put *points d'appui* behind Second Line into a state of defence;
Third and Fourth Lines.

Besides all this there were the following, by no means simple, undertakings:

1. Cut, collect, and cart all our material for trench work;
2. Manufacture our hand grenades from stores available, and train the Infantry in their use;
3. Construction of the huts behind the lines for the Rest Camps.

Later, when the two lines were drawing close together, the following additional calls were made on the Section:

1. Run out as many Saps as possible towards the enemy;
2. Commence Mining Operations against the enemy.

Of course, under the conditions that existed at that time the work could never have been done in some years. The only troops to assist the Field Companies at that time were 1 Fortress Company to each Corps. Well, let us follow through the different steps taken to overcome the difficulties.

The first and obvious method was to teach the Infantry to do all the simple work on the spot, and to continue training them until they could do all ordinary Field Engineers' work, thus releasing the R. E. for the more difficult.

The following items illustrate some of the work which can be, and is now, undertaken by the Infantry, under R. E. supervision—after a thorough course of instruction by the R. E., which before the war was left by them entirely to the Sappers:

1. Erecting wire entanglements;
2. Complete digging, revetting, loopholing, traversing and flooring of the Front, Support, Reserve and Communication Trenches of the 1st and 2nd Lines;
3. Repair of above-mentioned, necessitated by daily wear and tear;
4. Making any necessary Saps.

All the above needs no technical ability when the men have been once shown, and with a few weeks of supervision the Infantry can carry them out with perfect success.

This leaves the R. E. free for the following work:

Training the Infantry in the simpler branches of Engineering work;
Reserving for themselves the more technical duties, such as—

In the Front Line—

1. Bombproof Machine Gun Emplacements, which consists of concrete and R. S. J.;
2. Where the ground admits, construct deep shell-proof dug-outs;

In the 1st Line—

Strong points. These small works require very careful siting and concealing, and it is on them that, in the event of a portion of the Front Lines falling, time is gained for the Counter-attacks. These strong points should be weather-proof, and as comfortable as possible;

The same duties apply equally for the 2nd Line.

The construction of *Point d'appui,* or strong areas, in the Rear. Here much technical work can be done with concrete and steel joists for Machine Gun Emplacements. Infantry parties are essential to assist with digging, carrying and filling sand-bags, etc.

The work still remaining for the R. E.—which the R. E. Field Companies were originally expected to do, is—

1. Bomb manufacture;
2. Drainage;
3. Collection of material;
4. Mining.

When the call was made to the Field Companies to undertake Mining Operations, it was seen that this work could only be undertaken by them at the expense of the work on the trenches, so special *Mining Companies* were formed at Home and sent out at once.

The Mining Companies are allotted to different parts of the Front, as required.

The mining schemes are drawn out by the army, who inform the corps concerned, and are carried out by the companies.

When mining operations have once started, work has to be kept up at as fast a rate as possible and, to ensure success, reports of rate progress, etc., have to be sent in regularly and as soon as possible.

In the case of a mine being fired, reports are wired to the Controller, giving all details, and these reports are passed on by him to General Headquarters.

Cooperation again plays a very important part in the success of mining operations.

Though in no way part of his command, the Brigadier in command of an Infantry Brigade holding a length of trench is naturally very interested in the mining operations going on in this Front, and the Mining Companies work in close conjunction with him, obtaining the necessary working parties to deal with sand-bags, etc., and keeping him informed of progress of work, etc.

The usual gallery now used is about 4 feet high, 2 feet 6 inches wide at the top and 3 feet at the bottom, measured inside the timbering, and this means a section of some 12 square feet.

Galleries have been run out some 400 feet, which gives us about 5,000 cubic feet of earth to dispose of, which will mean some 4,000 sand-bags from each gallery.

The great secret of successful mining is "Silence," and it has been found that the most satisfactory method of disposing of this earth is to put it in sand-bags, and drag it to the head of the shaft by hand, or by a winch. Here the Infantry should take the bags over for use in their fire trenches. In the event of their having a

surplus, an excellent plan is to build a dummy parapet on any available ground high enough to cast a good shadow for aeroplane observation purposes. The Germans have been known to spend the best part of the day shelling such a dummy trench, which can only be distinguished with difficulty from a real one.

Work on the face of a gallery is carried out by three men—one working, one filling bags, and one resting, the number of the remainder depending on the length of the gallery.

The average rate of progress is about 12 feet a day, but galleries in favorable soil have been run at the rate of 32 feet in twenty-four hours.

The depth of the galleries varies according to the tactical requirements, and may vary from 12 to 120 feet.

With regard to the charges used, there are two distinct types:

a. A common mine, used with the idea of making a crater on the surface and destroying the enemy's work;

b. or Camouflet, used to destroy the enemy's mining works underground, and so charged as to leave the surface undisturbed.

Mines to produce craters have been charged up to 13,000 pounds, producing crater 60 yards long by 40 yards across.

The charges of Camouflets varies with the depth of the charge and the soil, and in some cases charges of 2 or 3 tons have been fired without disturbing the surface.

The explosives used are those obtainable at the time.

Ammonal has been used in large quantities with great success.

Drainage and ventilation are carried out by pumps, and continuous experiments have to be carried out to find the most silent, and at the same time, effective types.

Lighting the galleries is carried out usually by candles, but electric torches have to be used when the mines are being charged.

Collecting Material. This is, perhaps, the most important and at the same time most tedious of all R. E. work. Originally, the Companies cut what timber they could, and collected from houses and villages all suitable material, but the local supply soon became exhausted, and the matter had to be taken up on a large scale.

But there is one point which I am sure many officers—even R. E. officers—are ignorant of, and that is the quantity of material necessary for putting the trenches in a fit state for occupation in winter. One sees type drawings of various trenches and shelters which are put forward as models to be copied, but when one comes to work out the material necessary, one finds that it can not be obtained. There is never enough and the supply, cost what it may, must be increased.

The following is a detailed estimate made out for 1 mile of Front, including 1st and 2nd Lines and all Communications. It was made where breastworks are essential, owing to the low ground

being water-logged. It gives you some idea of the material required.

Wire Entanglement—
1,800,000 yards of wire, or 900 miles. Weight=110 tons.

Standards—
6 feet. 12,000.

Small Pickets—
12,000.

Trench Construction—
Sand-bags=6¼ millions. Weight=1,000 tons.

Corrugated Iron—
Some 36,000 feet run.
Timber, average dimension 3 by 3 inches=1,125,000 feet run.

Besides the above, large quantities of revetting material are required, including timber planks, wire netting, and expanded metal.

Now, as to the time taken to complete the construction of 1 mile of such trenches to make them fit for winter occupation:

An average man will fill and place in position on the parapet, parados, or dug-out, at the most, 25 sand-bags in one night.

So, to fill and place the 6,000,000 odd bags will take a Working Party of a Battalion about 240 nights work, or some 8 months.

But, and this is the point I wish to emphasize, if the Sappers are to complete the job without assistance from the Infantry, it will take a Field Company, with its usual working party of 80 men, some 6 years to finish.

This brings out the most important ideas:

1. It is essential for the Infantry to assist the Sappers with every man they can spare;
2. Do not put off the preparation of the trenches for the Winter Campaign until too late.

With every man working, it can not be done under 2 or 3 months, and the time to start is, at the latest, the end of July.

Of course, the times I mentioned just now—the 240 days and the 6 years—are only based upon dealing with the material required in the perfect trench. In actual practice these amounts of material never reach the trenches. But it is not until everyone grasps the enormous quantities needed that the supply will be increased.

With regard to the state of training already reached by the Infantry in Field Works, I should like to give the following example:

In one Division the Divisional Cyclists were handed over to the C. R.E. as a permanent working party to assist the R. E. They were allotted to a Field Company to be trained as a party for the construc-

tion of wire entanglements. This party, after a few weeks training, assisted by Sappers, total strength being 120 men, in 2½ hours ran an entanglement 1,200 yards long and 20 yards wide in front of a newly captured position. They used 117 miles of wire, 1,600 6-foot iron standards and 1,600 pickets. Five days were occupied, before the attack, in carrying up the stores for the work and placing them in a handy position to commence work at the required moment.

Now, I have only been able to give you a very small idea of the work performed by the R. E. I have tried to show how, with the small establishment of Engineers and the immense amount of work which the new type of warfare has necessitated, most of the old ideas on the legitimate duties of the R. E. have changed.

The respective spheres of action of the R. E. and Infantry are now separated by a stream, the size of which is a measure of the difference in technical knowledge.

The continual personal instruction of the Infantry in all matters, formerly supposed to be the exclusive province of the R. E., is gradually draining the stream, and bringing nearer the time when the Infantry will all be as skilled in Pioneer work as the regularly constituted Pioneer Battalions, while only the most advanced technical matters remain within the completely separated area of R. E. activities.

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Permanent Superstructures on Harbor Piers, Milwaukee, Wis., District.

BY

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In common with most of the harbors on the Great Lakes, the original works of harbor improvement along the west shore of Lake Michigan, such as breakwaters, jetties, and revetments, were constructed of timber. Practically all of the harbors are located at the mouths of rivers. The general method of improvement consisted in constructing two approximately parallel piers or jetties, from 150 to 400 feet apart, extending out into the lake until the desired natural depth was reached, and dredging a channel between them.

These piers or jetties were of timber construction, that being the cheapest material then available. In some cases cribs were built and sunk in place by filling with stone; in other cases the pier consisted of two parallel rows of round piling, with or without sheet piling, secured by wales, binders and tie rods, and filled with stone.

In all cases the superstructure, being that portion of the pier above the water surface, extending to a height of about 5 feet above mean lake level, was of timber and similar in construction to the submerged portion, or substructure. Timber below water is not subject to decay, and at most harbors it has been found that timber not more than 1 to 1½ feet above water remains sound for many years. While rebuilding the superstructure of the north pier at Milwaukee in 1903, white pine timber, about 1 foot above mean lake level, was found to be fully as sound as when placed in the original work in 1855, 48 years before. The upper courses of timber in cribs and the upper portions of pile jetties, are subject to more or less rapid decay, the usual life of the timber in those portions being from 12 to 16 years.

While timber remained low in price, and could be readily obtained, it was more economical to repair the superstructures by

replacing decayed by sound timber rather than with more permanent materials at a considerably higher cost. The average cost of labor and materials for rebuilding the upper 4 feet of timber superstructure on cribs was about $8 per linear foot of pier. About 15 years ago, however, there was a sharp advance in the price of timber. The price paid contractors for timber in the work advanced from an average minimum of about $17 per thousand in 1894 to an average maximum of about $44 per thousand in 1906. Since then the price has fallen somewhat, the average price paid contractors for timber in the work during the past 10 years being about $38 per thousand. Since 1904, practically all timber has been Washington fir, furnished to the contractor by the United States, the average cost of which, delivered to the contractor, has been about $20 per thousand. At present prices of labor and materials, the cost of rebuilding timber superstructure, 4 feet in height, is from $10 to $12 per linear foot of pier, an increase of from 25 to 50 per cent over the former average cost.

Owing to this increased cost of timber construction, it became desirable to develop some other method of repairing timber structures, which should be practically permanent and at the same time not so costly as to be uneconomical. It is the purpose of this article to describe the methods adopted in the Milwaukee district for building permanent superstructures on piers or jetties, being those structures which are built approximately normal to the shore, so that waves usually run along them. They are not subjected to as severe wave action as are breakwaters placed normal to the direction of maximum wave force; a lighter form of superstructure can therefore be used than for breakwaters. The methods of building superstructures on breakwaters will not be considered in what follows.

The permanent superstructures generally are of concrete. In special cases, however, superstructures of rubble stone, more or less carefully placed, have been constructed.

Concrete superstructures are cellular in type, consisting of two parallel walls connected at intervals of about 8 feet by cross walls from 12 to 18 inches thick, thereby forming open pockets or "cells" which are filled with rubble stone. The superstructure is built in monolithic sections, 24 or 25 feet in length, and is provided with a continuous walk of reinforced concrete slabs, supported by the cross walls.

In all cases where an old pier is to be provided with concrete superstructure of this type, the work has been done by hired labor

and use of Government plant. It frequently happens in cutting down the upper portion of an old pier that conditions arise requiring more or less modification of plan. These conditions can not be foreseen, being discovered only as the old work is removed. It is therefore scarcely practicable to do the work by contract under previously drawn specifications, except by providing for so many possible contingencies and throwing so much possible risk on the contractor, as to necessitate prices so high as to make the work much more costly than if done by hired labor when all risks are assumed directly by the Government.

In this connection it may be said it has been the general practice in this district to do directly by hired labor such work as is involved in considerable uncertainty as to execution, awarding contracts for such work as can be definitely specified and for which the risks assumed by the contractor can be fairly definitely foreseen. All risk has to be finally assumed by the Government in any event, as reliable contractors must provide for same in their bids, whether such risks are ordinary or extraordinary. If the possible unfavorable contingency does not arise, in the case of a contract, the Government has paid for it just the same, and the benefit inures to the contractor; whereas, if the work is done by hired labor, the Government profits accordingly.

The work of building cellular superstructures on old piers does not require a large or special plant. The plant now being used in this district for such work consists of a floating derrick of 3 to 5 tons capacity, two flat scows, and a small gasoline tug. A steam-driven concrete mixer, having a capacity of about two-thirds of a yard of finished concrete, is placed on one scow; the other scow is used for carrying materials. With this plant and a crew of about 15 to 20 men, from 200 to 300 linear feet of superstructure is built per month, including the cutting down of the old pier.

Care is taken to hold the pile walls together by new wales and binders secured by steel tie rods as the work of cutting down the pier progresses, so as to prevent the pier from spreading. By exercising care, there is no difficulty in holding the pier so as to secure excellent alignment for the concrete superstructure. Fig. 1 shows a portion of the north pier at Kewaunee, Wis. It will be noted that the alignment of the concrete superstructure is very nearly perfect, although there were many irregularities in the alignment of the pile pier.

Much of the old pile pier in this district consists of two parallel rows of round piles, driven in close contact, secured by wales, binders and tie rods, and filled with stone. The cross section of the

concrete superstructure built thereon is shown by Figure 2.

The stone is first removed from the pier to the required depth. The piles are then sawed off as close to the water surface as possible. In the figure they are shown as cut off 1 foot below datum. The water level of Lake Michigan for several years has been from 1 to 2 feet below the datum plane of this district, which is mean lake level 1860-1875, corresponding to 581.63 feet above mean tide at New York City.

Fig. 1. Kewaunee North Pier.

After securing the pier with new wales, binders and tie rods, the stone filling is roughly leveled to about the tops of the wales. The pile heads, projecting about 6 inches above the wales, are then capped with 1 by 12 inch boards, and boxed in on the sides with ½ by 6 inch weather boards, so as to prevent concrete from leaking between the piles.

The forms are then set up and secured in position. The form for a section consists of two outside pieces, two core boxes, and two

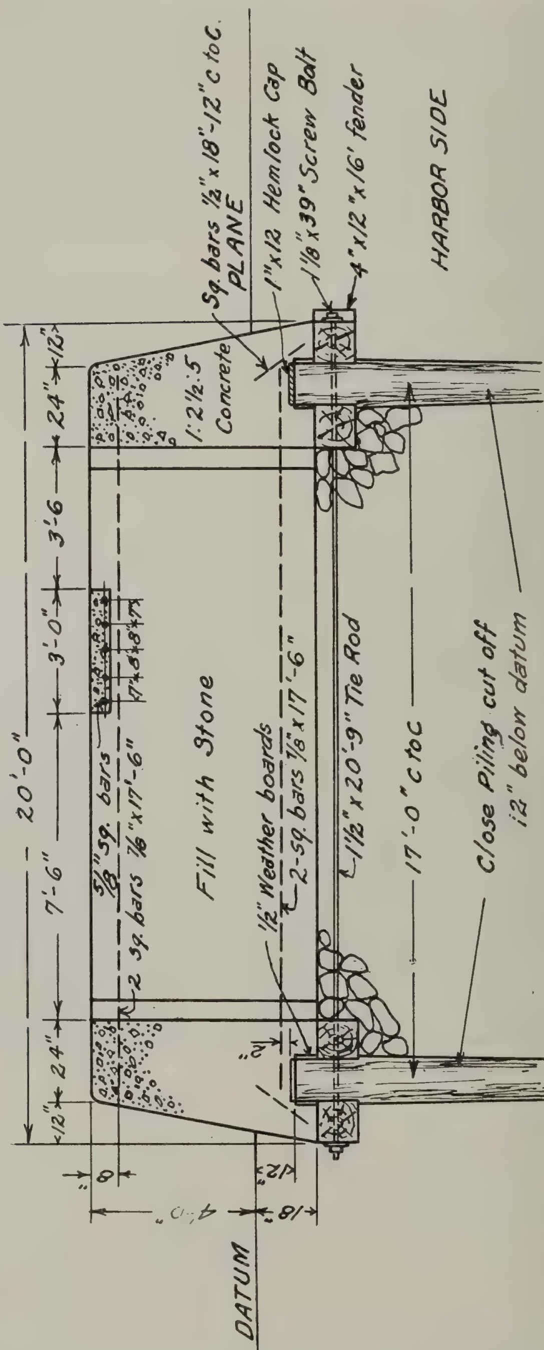


Fig. 2. Concrete Superstructure on Old Pile Pier.

half-core boxes. The general arrangement of the form is shown by Fig. 3.

An approved form of core box, which has been successfully used, is shown by Fig. 4. This box is so made that it can be readily withdrawn from the hardened concrete. It is built usually of 2-inch plank secured to upright studding, and in four parts, being joined at the middle of the sides. Notches (not shown in Fig. 4) are cut in the longer sides of the box to form the recesses in the cross walls for the slab walk. These notches may be seen in Fig. 3.

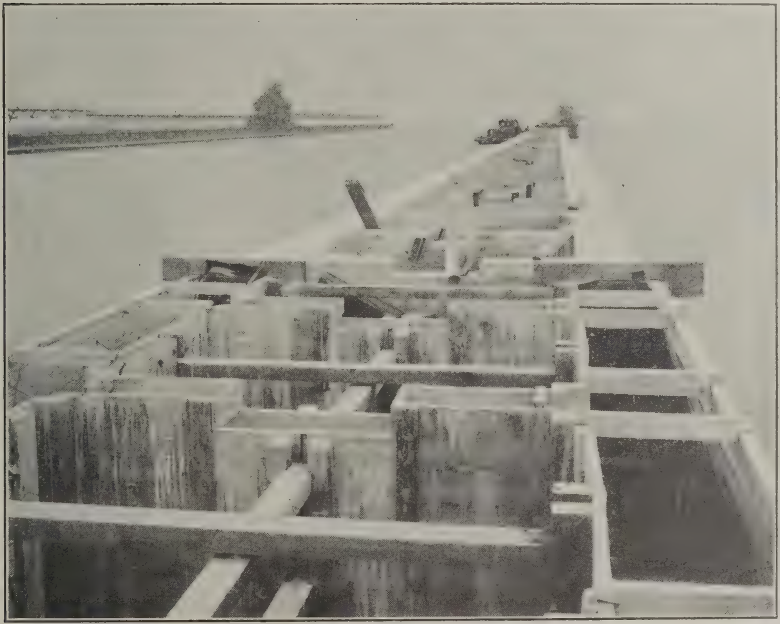


Fig. 3. Kewaunee South Pier. Under construction.

The core box is set up on the deck of a scow or other convenient place. After the wedge-shaped keys ''a'' and the struts ''d,'' resting on pins ''c'' are placed in position, the four parts or corners are drawn firmly together against the shores and wedges by the bolts ''b.'' The box is then placed in position in the form by means of a derrick.

To remove the box from the finished concrete the bolts are loosened, after which the shores are taken out, and the wedge keys removed. The shores are then dropped back into place and the core box is pulled away from the concrete by tightening the bolts until the shores prevent further movement. The box is then lifted

by the derrick out of the concrete, as an assembled unit, and is ready for re-setting.

It will be noted that the side walls rest on the round piles, the heads of which are imbedded in the concrete. While the cross walls are formed on the stone filling, no reliance is placed on the filling as a support for the superstructure. The cross wall is designed as a beam, supported at the ends by the side walls, which in turn are

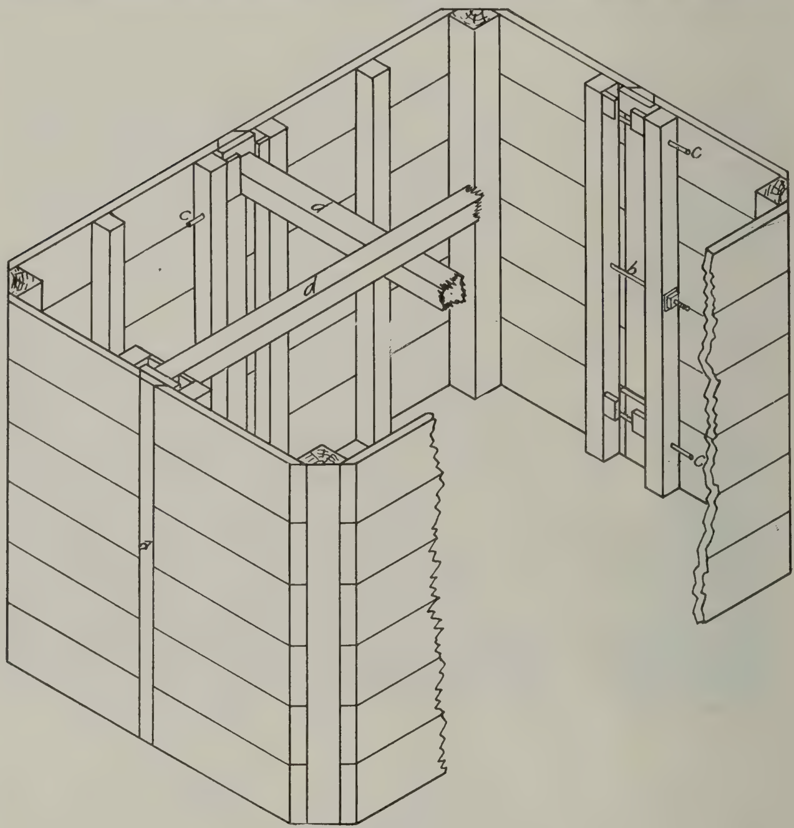


Fig. 4. Core Box.

carried by the piles. Each section, therefore, is a complete unit supported by the walls of the pier.

The cross walls are reinforced with steel bars, the purpose of which is not only to enable the walls to act as beams, but also to serve as ties between the side walls. The heads of the piles being imbedded in the side walls, the superstructure holds the pier walls together independently of the tie rods passing through the wales and piles. Should a section of waling be destroyed or some of the

tie rods passing through same be broken, the pile walls would still be held together by the concrete. Short reinforcing bars, placed at 12-inch intervals at the toes of the side walls, enable the concrete to act in tension.

The concrete slabs are molded independently in gang molds, and are reinforced with ⅝-inch square steel bars. The slabs are of a length to span a single opening between cross walls. They are set in the recesses formed in the cross walls on a thin mortar bed, the spaces between ends of slabs being filled with mortar.

Before placing the slabs, the superstructure is filled with stone. It has been the practice recently to spread a thin layer of concrete, about 6 inches thick, over the top of the stone filling. This prevents stones from being washed out by wave action, and also discourages fishermen and others from removing the stone for anchors and other purposes, a practice which in some instances has rather seriously depleted the stone filling.

In some cases the pile pier consists of a row of close round piling on the inner or channel side, and sheet piling with round piles spaced about 4 feet centers on the outer or lake side. The general method of construction is, however, practically identical with that just described, the sheet piling being cut down to a level with the upper surface of the wales and binders and the piling projecting 6 inches above same and imbedded in the concrete.

The total cost of the concrete superstructures described, including the cost of cutting down and preparing the old pier for reception of the superstructure, has been from about $12 to $15 per linear foot of pier, depending upon the width of pier, which usually varies from 14 feet to 18 feet center to center of parallel rows of round piles.

An adaptation of the form of superstructure described has been used for original pier construction. The cross section of the adopted design is shown by Fig. 5. In this case the sides of the pier are alike, consisting of round piles spaced 4 feet centers, with 9-inch triple-lap sheeting; 12 by 12 inch spreaders are used between round and sheet piles. The general method of construction is the same as that previously described. All work constructed according to this design has been done by contract. The timber, cement, and reinforcing steel were furnished to the contractor by the United States; all other materials were furnished by the contractor. The following is the approximate cost of building 100 linear feet of this style of pier in this district by contract, including the cost of materials furnished by the United States:

Materials.	Unit cost.	17-ft. Pier—16-ft. Water.		14-ft. Pier—12-ft. Water.		11-ft. Pier—8-ft. Water.	
		Quantities	Cost.	Quantities	Cost.	Quantities.	Cost.
Round piles..........lin. ft..	$0.37	1,450	$536.50	1,250	$462.50	1,050	$388.50
Sheet piles..........ft. b. m...	44.00	39,600	1,742.40	32,400	1,425.60	25,200	1,108.80
Timber..........ft. b. m...	47.50	10,633	505.07	10,633	505.07	8,033	381.57
Bolts, spikes, etc..........lbs...	.05	3,761	188.05	3,412	170.60	3,064	153.20
Concrete superstructure...cu. yds...	10.50	98	1,029.00	93	976.50	87	913.50
Concrete slabs..........cu. yds...	12.00	12	144.00	6	72.00	6	72.00
Reinforcing bars..........lbs...	.02	3,249	64.98	2,303	46.06	2,003	40.06
Stone—filling and riprap.....tons...	1.60	2,000	3,200.00	1,100	1,760.00	425	680.00
Cost of 100 linear feet of pier......	....	....	$6,904.93	......	$5,418.33	......	$3,737.63

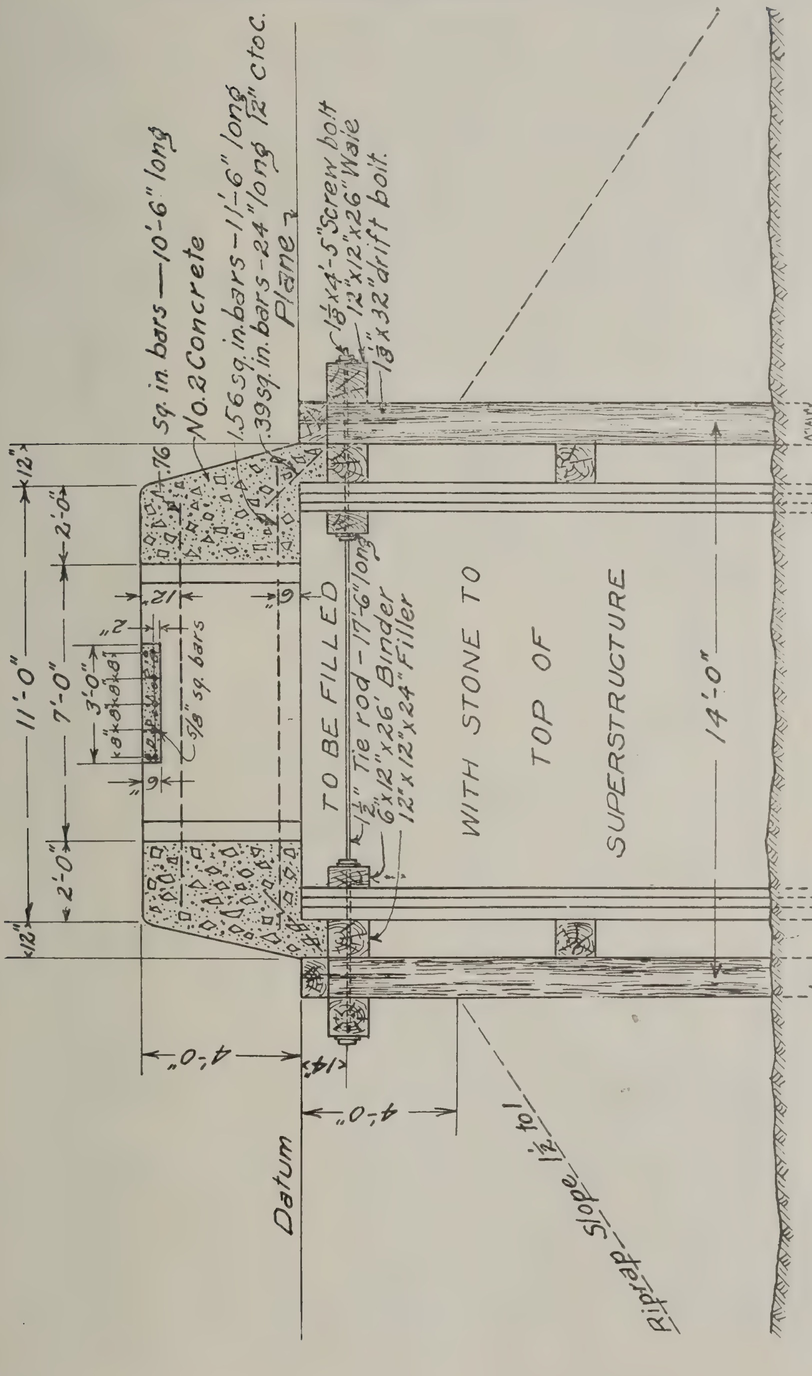


Fig. 5. Pile Pier with Concrete Superstructure.

Fig. 6 is the cross section of the adopted method of building concrete superstructure on sheet-pile revetments. It is built in sections about 10 feet in length. The work presents no unusual conditions and is similar to that already described. Several hundred feet of this style of superstructure have been built at Sturgeon Bay Canal at a cost of about $3 per linear foot, including the cost of cutting down and preparing the piling for the superstructure. The superstructure has proved entirely satisfactory after six or seven years' experience. No repairs to the concrete have been

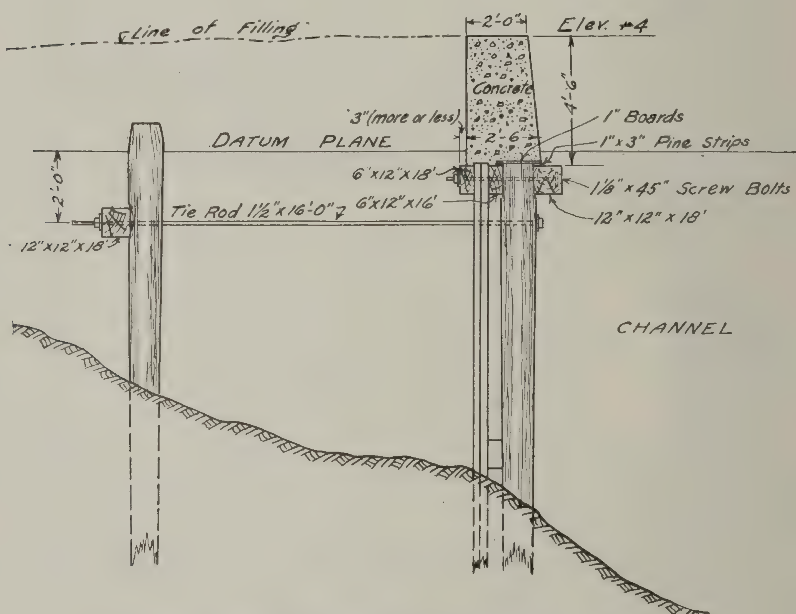


Fig. 6. Concrete Superstructure on Pile Revetment.

necessary. In one instance a steamboat ran into the revetment, forcing it back several inches. The waling was somewhat damaged, but no injury was done to the concrete, and the revetment sprang back into place.

In building concrete superstructure on crib piers a slightly different design is used, as shown by Fig. 7. The cellular type is employed, but foundation blocks are molded on the cribs and the superstructure is then built on these blocks. The crib walls are cut down to about 2 feet below datum (mean lake level, 1860-1875). Only full courses of timber are removed, however; the timber is

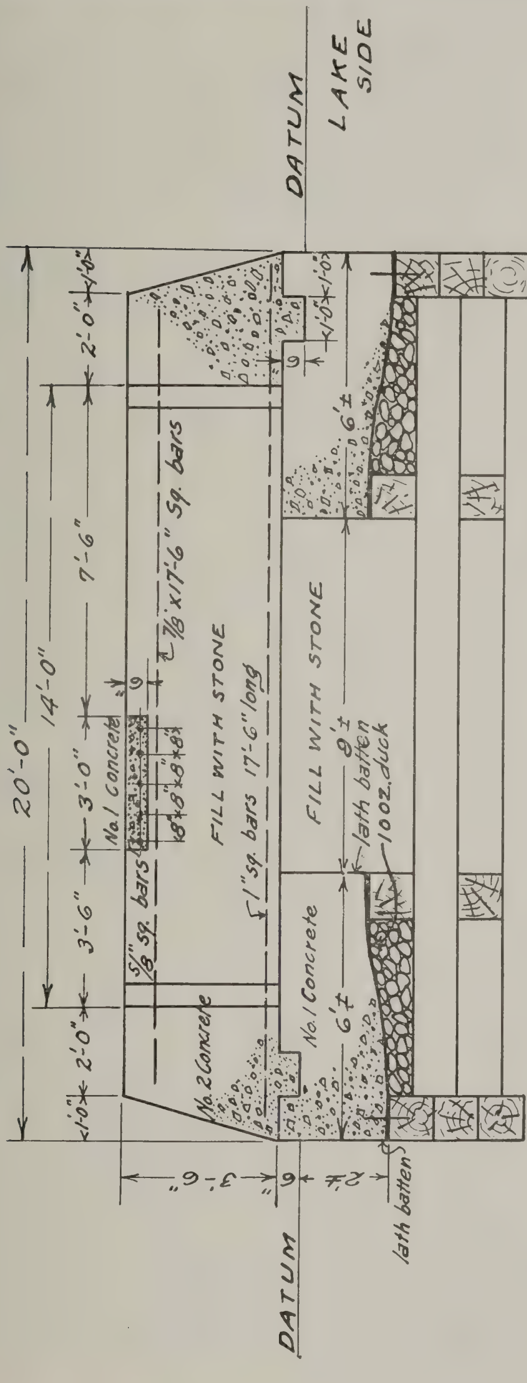


Fig. 7. Concrete Superstructure on Old Crib Pier.

removed to that course, the top of which is at or just below the prescribed razee plane.

As the cribs are usually either 50 feet or 100 feet in length, superstructure sections are molded in lengths of 25 feet, so that a section will be coterminous with the crib. It has been found when concrete has been built on two cribs, spanning the interval, the lateral movement of the cribs, due to wave action, ruptures the concrete at the interval.

Foundation blocks are molded in place, in lengths of 25 feet. As the bottom of these blocks is usually below the water surface, a canvas dam is used to check oscillation of the water in the form, thereby preventing the cement from being washed out of the submerged concrete while being deposited. The dam consists of a piece of 10-ounce single-filled duck, 8 feet wide and 28 feet long. After the form has been set up, the canvas is spread over the timber and stone on which the foundation block is to rest, being held in place under water by stones. The edges of the canvas are then secured to the bottom of the form, using lath battens and shingle nails. The vertical corners of the form are made practically water-tight by tacking on battens, triangular in cross section, with strips of canvas behind them.

It is not advisable to carry the canvas dam up on the sides and ends of the form. To secure good concrete faces, spading against the form is required and at times considerable force is necessary. This spading would tear the canvas and destroy the efficiency of the dam. No attempt is made to have the dam absolutely water-tight or to deposit concrete in the dry; quiescent water is secured, in which the concrete is deposited. With reasonable care, and with waves not exceeding 6 inches in height, very satisfactory results can be obtained.

A convenient method of securing the outside form to the side of the crib while molding foundation blocks, is to nail pieces of 2 by 4 inch timber, each about 12 or 15 inches in length, at suitable intervals along a line about 6 inches from the lower edge of the form, making steps which rest on the crib wall. The old drift-bolts are left projecting above the timber of the crib, and serve not only as anchorage for the concrete blocks, but afford a means of securing ½-inch bolts provided with hooks at one end placed around the drift-bolts, and a nut at the other end. These bolts project horizontally through the side form which, by means of the nuts, is then drawn up tightly against the crib wall. Laths are nailed near the upper edge of the form to mark the upper surface of the con-

crete, which is roughly finished to that plane. While depositing concrete in the form, the 2 by 4 inch steps are pried off with a spade, the hook-bolts being sufficient to hold the form firmly in place. After the form is removed, the hook-bolts are readily cut off flush with the concrete face by means of a hack-saw.

A similar method is applicable to the walls of the concrete superstructure, old drift-bolts being imbedded in the foundation blocks at the time of molding them. This method of drawing up the form is preferable to using wire, which invariably stretches, causing a leaky form.

Naturally, the cost of superstructure of this type is more expensive than that described for pile piers. By hired labor, however, it has been built on cribs 20 feet wide for about $18 per

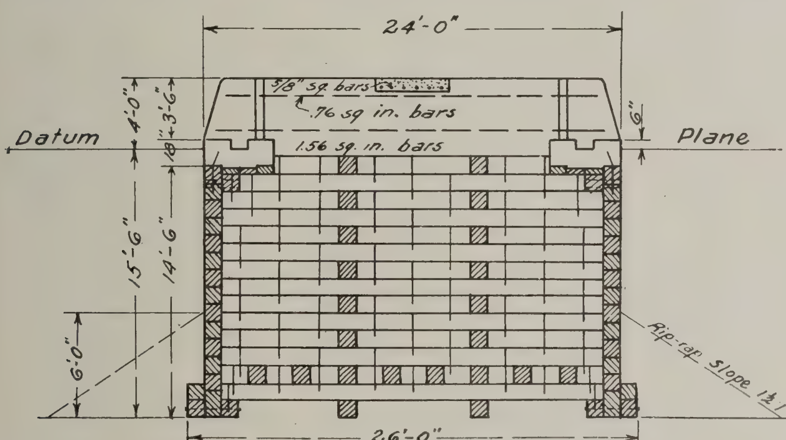


Fig. 8. Crib Pier with Concrete Superstructure.

linear foot of pier, including cost of cutting down and preparing the cribs.

In some cases it has been desirable to build crib substructures provided with concrete superstructures, as original work. The design shown by Fig. 8 has been found to be well adapted for this form of construction. The crib is of ordinary construction, but carried to such height that when sunk on its foundation the timber will be wholly below water. While the crib is afloat at the construction dock, concrete foundation blocks are molded in place. These blocks are made of such height as will insure their upper surfaces being well above water when the crib is sunk in position. On these foundation blocks, cellular concrete superstructure is then built in a manner similar to that previously described.

Unless the height of the crib is very considerable, the foundation blocks will cause the crib to sink unless further buoyancy is supplied. This is readily done, however, by placing water-tight boxes, open at the top, in the pockets of the crib.

Each box is provided with four 2-inch holes in the bottom, which are stopped by long-handled plugs reaching to the top of the box. The crib is sunk in position by admitting water into the boxes through these holes. When the boxes are full of water the crib usually rests securely on the foundation; but in case it does not, sufficient stone ballast is placed on the concrete blocks to anchor it firmly on the foundation before filling the pockets with stone. After the crib rests firmly on the foundation the boxes are released and lifted out by a derrick, the water running out through the holes in the bottom as the box is slowly raised. As soon as the boxes have been removed, filling the crib with stone is commenced.

The following tabulation shows the size, number of boxes, etc., which have been used in actual construction:

Size of Crib.	Size of One Box— Length.	Width.	Height.	Displacement per box. Tons.	No. of boxes used.	Draft of crib. Feet.
100′×24′×14½′	6′ 8″	6′ 5″	6′ 6″	5.5	5	13
100′×24′×12½′	6′ 8″	6′ 5″	6′ 6″	5.5	7	11
100′×20′×10½′	6′ 8″	5′ 3″	6′ 6″	4.5	12	9
100′×20′× 8½′	6′ 8″	5′ 3″	6′ 6″	4.5	14	7

The cost of one crib, 100′×24′×14½′, complete with superstructure, but exclusive of foundation and riprap, at contract prices prevailing in this district, is about $7,850.

This method of construction has proved very satisfactory. About 1,700 linear feet have been built, of which 400 linear feet was provided with solid instead of cellular superstructure. Cribs varied in height from 8½ to 14½ feet, but there was no difficulty in providing the additional buoyancy necessary to carry the concrete foundation blocks at a shallow enough draft to float the cribs easily over the foundations, which were constructed of rubble stone.

Within the last year a method of rebuilding superstructure on the inshore portions of piers, with ordinary rubble, has been used. The cross section of this type of superstructure is shown by Fig. 9. This method can be economically employed where the depth of water on the outside of the pier does not exceed 6 or 8 feet.

The timber was cut down to about datum, after which common

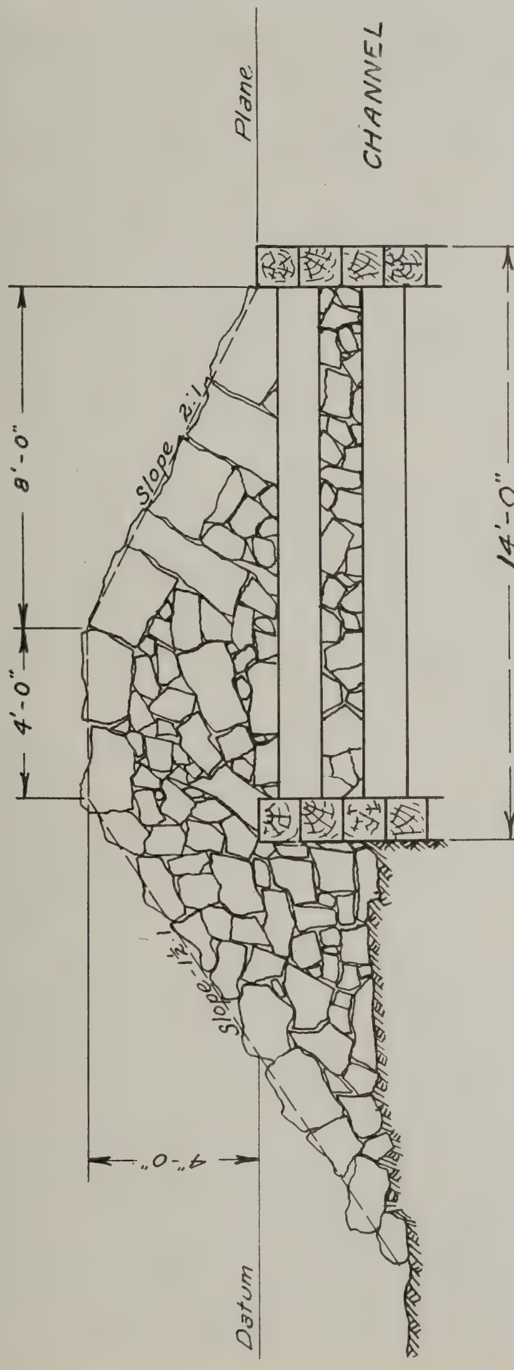


Fig. 9. Rubble Superstructure on Old Crib Pier.

rubble stone was roughly piled as shown, care being taken to place stones on the channel face so as to interlock, in order to prevent displacement by ice action. The channel face is left purposely rough, tending to destroy waves racing inward along the pier.

The work was done entirely by hired labor, stone being brought from quarries on a Government-owned barge in tow of the U. S. steamer *Manitowoc.* The stone loaded on barge at quarry cost 59 cents per ton. The total cost of stone, unloaded on the pier, but not including cost of placing channel slope, was about $1.20 per ton, and from 2½ to 5 tons per linear foot of pier was required, depending on depth of water on outer side of pier. The total cost of stone in place, but not including the cost of cutting down the old pier, was about $1.75 per ton, or from $4.50 to $9 per linear foot of pier.

Sufficient time has not yet elapsed to state positively as to the complete success of this method. So far the superstructures are entirely satisfactory, and it is believed they will prove fairly permanent. The advantage of this form of construction over concrete, aside from its cheapness, is that it can be done without employing special plant or specially skilled labor, and can be carried on at seasons of the year when concrete work has to be suspended.

COMMENTS *by* MAJ. H. B. FERGUSON, *Corps of Engineers; District Officer.*

The superstructures described by Mr. Tompkins have been found satisfactory. The test of durability is more severe than in most concrete structures. Freezing of the concrete, and abrasion due to moving ice, are the chief cause of destruction. Experiments, in a minor way, are being made to determine the most suitable concrete to meet these conditions. Various combinations of sand, gravel, broken stone, and stone dust are being tried.

In this district large stone, suitable for rubble-mound breakwaters, is not economically available. The essential mass and stability is obtained by use of concrete and smaller stone. The concrete forms a shell to protect the smaller stone. Beginning at the shore end of a breakwater, the smaller stone needs no protection up to depths of about 8 feet. The pile pier with cellular concrete superstructure has been used in depths up to about 16 feet, and is to be used in the near future in depths up to 18 feet. In depths over 18 feet, concrete caissons are used. As the pile pier type is less costly than the caisson or any other breakwater, it is desirable that this type be used for as great a distance on the shore end of a breakwater as experience will justify. To determine the practicable extension of the use of this type, as well as to increase the durability of concrete used, are the main features for future consideration.

Miscellaneous Notes.

The First Effective Use of Rifle Cannon in Sieges.

The first effective use of rifle cannon for breaching purposes in siege operations appears to have been in the bombardment of Fort Pulaski, Savannah River, Georgia.

Fort Pulaski was a pentagonal brick masonry fort, casemated on all sides, the walls being 7½ feet thick and 25 feet high. It mounted one tier of guns in embrasures and one in barbette. It was built on an island near the mouth of the Savannah River, and lay between the two channels of the river. The main, or north, channel was over 2,500 yards wide, measured across to a swampy island on the north side of the river. The south channel was narrower and directly opposite the fort; the south side of this channel was only about a thousand yards from the fort, but the shore consisted of a swampy island quite unsuited to the location of breaching batteries. Further seaward, however, along the northern or channel edge of Tybee Island, there was a narrow ridge of sand on which batteries could be constructed.

The operations against this fort began in January, 1862, and were under the charge of Brig. Gen. Q. A. Gillmore, U. S. Volunteers (Captain of Engineers), both as Commanding Officer and as Chief of Engineers.

Prior to this time the greatest range at which attempts had been made to breach masonry work by cannon-fire was about 1,000 yards, and the military authorities were practically unanimous in the opinion that an attempt to breach a work at greater ranges could be successful only with the expenditure of an unjustifiably large amount of ammunition.

Although the only available sites for batteries with which to breach at Fort Pulaski were on the northern edge of Tybee Island, at ranges varying from 1,700 to 3,000 yards, yet General Gillmore had sufficient confidence in rifle cannon to make the attempt, but during the time of preparation he was subject to severe criticism.

He persevered, however, and the bombardment of the fort was begun on the morning of April 10, 1862, continued throughout that day, and on the next day until the fort surrendered in the afternoon.

The siege artillery consisted of 14 heavy mortars, 10 large smooth-bore guns, and 10 rifle cannon.

In submitting his official report upon this siege (Professional Papers, Corps of Engineers, No. 8) General Gillmore comments first, on the unsatisfactory results obtained with the mortars, the fire of which was so inaccurate that less than 10 per cent of the mortar projectiles fell within the limits of the fort. He then comments upon the great effectiveness of the breaching batteries in making a practicable breach in masonry wall 7½ feet thick and cutting openings into two casemates, from a mean range of about 1,700 yards. He shows by reference to previous experience and experiments that such a result was unprecedented, but from the experience at Fort Pulaski he concludes:

> With heavy James or Parrott guns, the practicability of breaching the best constructed brick scarp, at 2,300 to 2,500 yards, with satisfactory rapidity, admits of very little doubt. Had we possessed our present knowledge of their power, previous to the bombardment of Fort Pulaski, the eight weeks of laborious preparation for its reduction could have been curtailed to one week, as heavy mortars and columbiads would have been omitted from the armament of the batteries, as unsuitable for breaching at long ranges.
>
> It is also true beyond question, that the minimum distance, say from 900 to 1,000 yards, at which land batteries have heretofore been considered practically harmless against exposed masonry, must be at least trebled now that rifled guns have to be provided against.

About a year and a half later, that is, in August and September, 1863, General Gillmore was in charge of the siege operations against Fort Wagner on Morris Island at the entrance to Charleston Harbor. Here again he made use of heavy rifled guns, but at ranges of slightly less than a thousand yards. This fort, however, consisted of earthworks only, and the contrast between the effectiveness of the fire of these rifled guns against the masonry at Fort Pulaski and the earthworks at Fort Wagner is very interesting. In his report on this subject, General Gillmore states:

> The attempt to form an opening into the bomb-proof by breaching failed for want of time. The heavy projectiles were slowly eating their way into it, although their effect was astonishingly slight. Indeed, the penetration of rifle projectiles, fired into a sand parapet standing at the natural slope or approximately so, is but trifling. They are almost invariably deflected along

the line of least resistance, or one departing but slightly from it, scooping out in their progress a small hollow, the contents of which are scattered but a short distance. Under such circumstances, the general effect produced by firing a large number of successive shots, within a small area of, say, from 15 to 20 feet square, is by no means commensurate with the necessary expenditure of ammunition.

. . . .

The two controlling conditions of the case before us must not, however, be lost sight of, viz:

1st. That the slope fired at was flat, the angle of inclination being even smaller, after a few shots had been fired, than the slope which sand naturally assumes.

2nd. That a very large proportion of the sand thrown up by each shot fell back within the area struck by the successive shots; or, in other words, within the area fired at.

With these conditions borne in mind, the deduction does not appear as startling as when first brought to view

During and after the siege of Fort Wagner, Fort Sumter, a brick masonry fort, was bombarded from ranges comparable with those used at Fort Pulaski. The result, as shown by the report and the drawings, was the practically complete destruction of all exposed masonry, though by means of sand-bag parapets the fort was enabled to hold out and did not surrender until February, 1865.

First Military Use of Searchlights.

As far as can be learned, the first attempt to use searchlights in military operations was made by Brigadier General Gillmore, U. S. Volunteers (Major, Corps of Engineers), in the siege of Fort Wagner, on Morris Island, Charleston Harbor, in the summer of 1863.

His report on this siege is published in Professional Papers, Corps of Engineers, U. S. A., No. 16, entitled: "Engineer and Artillery Operations against Defences of Charleston Harbor."

On page 54 of this report, General Gillmore states: "An attempt" on August 10, 1863, "to illuminate the waters near Cummings Point with two calcium lights placed in the left batteries was but partially successful, as the distance (over 3,000 yards) was too great for the apparatus which we had. The idea was to throw a cone of light upon the water approach, and station the guard boats in the obscurity just outside the lateral limits of the cone. The plan, I am convinced, was entirely practicable, and with powerful reflectors, and an efficient picket boat organization, would have given decisive results."

On page 70 of the same report he states that on September 5, in the operations against Fort Wagner, "powerful calcium lights to aid the night-work of our cannoniers and sharpshooters, and blind those of the enemy, were got in readiness. . . . The calcium lights turned night into day, and while throwing around our own men an impenetrable obscurity, they brilliantly illuminated every object in front, and brought the minutest details of the fort into sharp relief." Although not specifically stated, it would appear that neither of the lights was injured by the enemy's fire.

In the above connection the following extracts are quoted from the journal of Maj. T. B. Brooks, who was in immediate charge of the engineering operations of the siege:

> August 10, . . . Doctor Grant undertook to light up Cummings Point with two calcium lights, placed in the left batteries, distant 3,000 yards. The object was to reveal to our gunners any of the enemy's succor-boats that may be attempting to communicate with his forces on Morris Island, and interrupt the operations with our fire. On the night of August 4th Captain Payne, the scout, and party, were captured while repeating their endeavors to discover these relief boats. Neither plan fully succeeded.
>
> September 3. . . . Began, to-day, the construction of additional mortar platforms in the fifth parallel. Made a position on the left of the second parallel for the calcium light to be used against Wagner.
>
> September 6. . . . The whole of the superior and the upper portion of the exterior slopes of the south face of Wagner were plainly seen this night from the effect of the calcium lights stationed at the left of the second parallel.

These calcium lights appear to have been located about 750 yards from the south face of the fort.

Rock Removal Manhole on Suction Pipe of a Hydraulic Dredge.

By

Mr. Oswald Quinlivan, *Mechanical Engineer*,

and

Mr. C. B. Gibson, *Inspector*.

The experience of this office[1] with stone boxes, often installed in the suction line of hydraulic dredges, has been such as to convince everyone who has been connected with their operation that they not only fail to accomplish the purpose for which designed, but even cause additional delays and stops to the dredge.

The stone box is simply a cast iron box inserted in the suction line at the rear end of the ladder or between forward bulkhead of dredge and main pump, with the connection to the pipe in op-

[1] U. S. Engineer Office, Albany, N. Y.

posite ends of the box near the top and a trap door in its bottom for clearing of accumulated material. Its purpose is to collect stones and other large objects before they reach the pump and "plug" it or otherwise damage the runner. In theory, the bottom of the stone box being a foot or so below the level of the bottom of the pipe and the cross section of the stream being much enlarged at the box, the stones will drop into the box and remain there until removed through the door in its bottom.

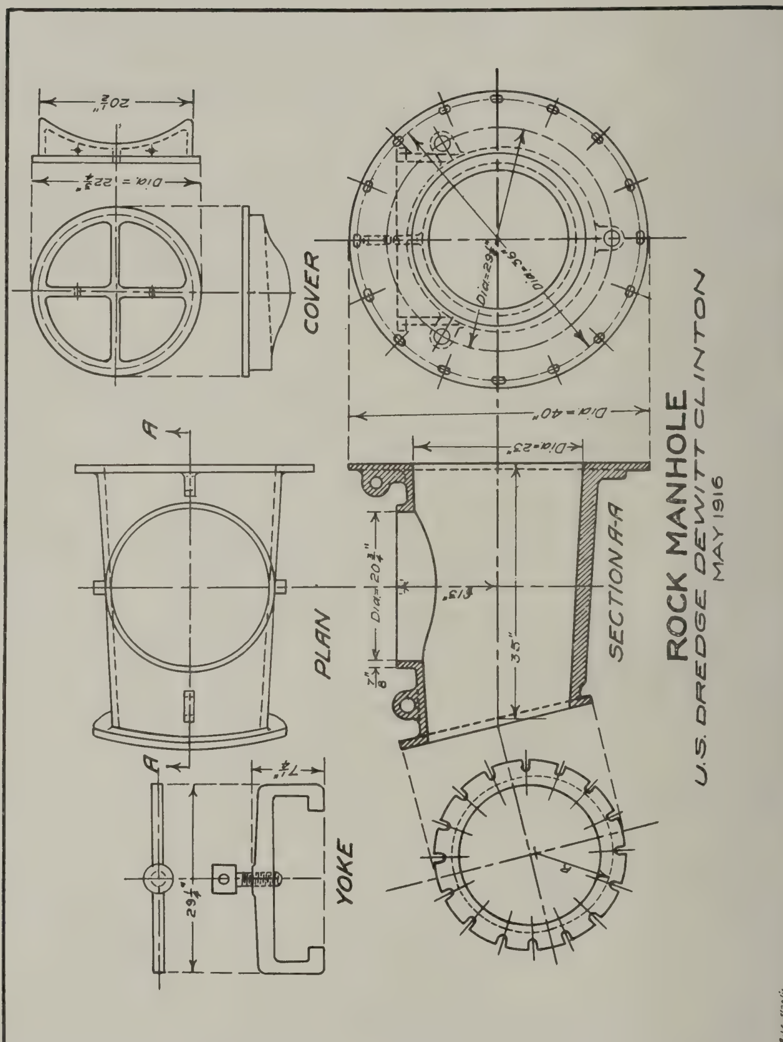
In practice small stones in large numbers, which would ordinarily go through the pump without trouble, are deposited in the stone box, which rapidly fills up and thereby loses its usefulness as a stone catcher. In case the stone box is in the hold of the dredge, the contents of the box, when cleared out, fall into the bilges of the dredge from which they have to be removed, usually by hand, at a considerable expense.

Furthermore, it is very hard to keep the door of the stone box air-tight, certainly much harder than to keep a manhole cover tight, and this often seriously impairs the vacuum in the suction line.

A much better arrangement is a large manhole placed in a somewhat enlarged section of the suction line immediately ahead of the pump, the manhole made sufficiently large for the removal of any stone which could traverse the suction line to this point, and with a cover strong enough to preclude any possibility of its breaking, with the probable consequence of sinking the dredge. Usually the manhole cover is held in place by some form of yoke clamp; this arrangement, while giving the necessary strength, admitting of opening and closing the manhole with the least possible delay.

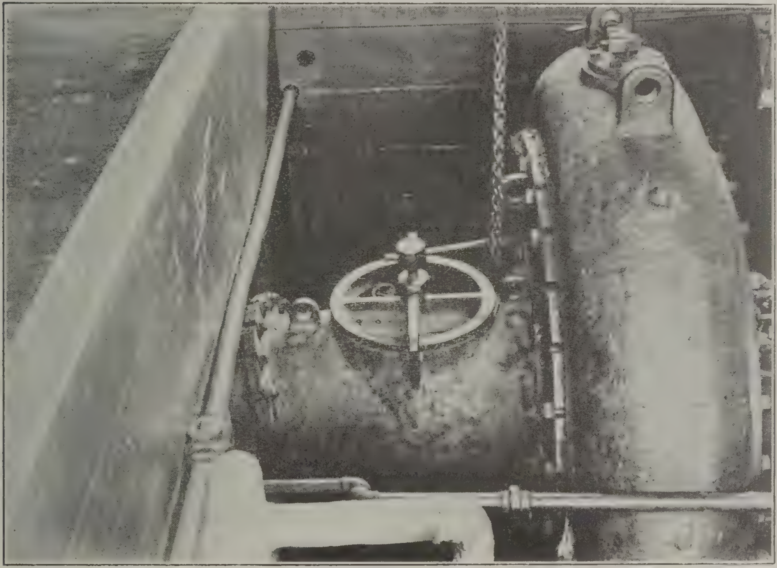
The section of pipe containing this manhole is usually tapered, the diameter of pipe increasing toward the pump. This taper serves a two-fold purpose; first, that of increasing the annular space between the runner hub and nut and the pipe walls, thereby allowing small stones to enter the pump which would otherwise be stopped but which can properly be handled by the pump, and second, making easier the entrance of a man into the pump for the purpose of clearing or inspecting it.

This manhole section next the pump is in no sense a stone box, nor is it intended to exert the same function for which the stone box is designed, viz, the stoppage of large stones before the pump is reached. Although stone boxes are still frequently installed on hydraulic dredges at time of building, it is an accepted fact,


ROCK MANHOLE
U.S. DREDGE DEWITT CLINTON
MAY 1916
COVER
PLAN
SECTION A-A
YOKE
Dia. = 40"
Dia. = 23"
Dia. = 36"
Dia. = 22¾"
20¾"
Dia. = 20¼"
35"
29¼"
7¼"
A
A

among the majority of men who have had much experience in the actual operation of these dredges, that no suitable appliance has yet been devised which will satisfactorily accomplish this much desired result, and there seems no chance of such a thing being perfected in the near future.

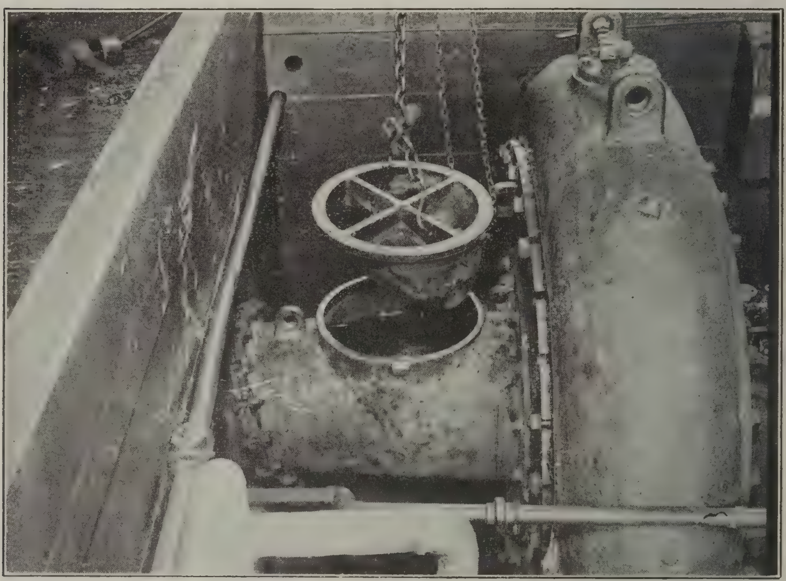
Since it has so far been found impossible, as previously described, to stop the incoming stones by the use of a stone box or other appliance, the stones go on through the length of the suction pipe to the entrance to the pump, where those large enough to become jammed in the pump, or in a bend or sleeve connection in the dis-



charge line later, are usually prevented from going further by the runner nut and hub of the impeller or by the vanes of the runner itself. Here they lodge, partially or completely plugging the suction line, until removed through the rock manhole designed for this specific purpose.

In our experience with the rock manhole, it has been found that there are fewer delays due to the plugging of the suction line and seemingly no more stops to clear the pump than was the case with the stone box in use, the small material going where it naturally should go, to the pump, and the large stones being readily removed through the rock manhole.

The intake end of the suction pipe at the cutter is for similar reasons not provided with any bars or gratings, since it was found that they were the cause of constant stoppages. Any stone not large enough to pass the bars would be held there by the suction and the end of the pipe quickly become plugged, requiring a stoppage of the pump before the stones would fall off. It may be added that much of the material handled was glacial gravel, containing in many locations a large proportion of cobbles or "nigger-heads" of all sizes, with some one-man riprap along the dikes.



Submarine Rock Excavation: Borings for Contractors' Estimates.

By

Mr. J. H. Rostock, *Assistant Engineer.*

In submarine rock excavation, the method usually adopted to determine the amount of rock removed and to be paid for on contractors' estimates is to require the overlying material to be removed first, and then to take measurements to determine the position of the rock surface with reference to a plane previously fixed, and which, in waters affected by tides, is usually the plane of mean low water. In this river and harbor district (First District,

New York City) these measurements are ordinarily made with a pole about 2 inches in diameter, graduated for each foot and tenth of a foot, and fitted with a tempered steel point five-eighths of an inch in diameter. Since it is impracticable to remove all of the material overlying the rock, this steel point is made of sufficient length to insure penetration to the underlying rock surface. Soundings are also taken with a similar pole, but fitted with a disc instead of a steel point, to determine the depth of water over the material overlying the rock. The data thus obtained are used in calculating the amount of each class of material, rock and the material overlying it, situated above the plane of the depth required to be made by excavation.

There is now in process of completion in this district a channel in the East River, New York, between North Brother and South Brother islands. The work required in making this channel includes the excavation to a depth of 26 feet below mean low water of ledge rock, and a layer of overlying compacted material varying in thickness up to about 7 feet as a maximum.

Before commencing this work, it was realized that, owing to the strong tidal currents here, and to the difficulty of penetrating this compacted material, the unit cost of securing by the usual method data for a reasonably accurate determination of the volumes of the materials to be removed, would be inordinately high; also that to require the dredging of the overlying material and the ledge rock in two operations, instead of one, would result in a comparatively high cost per unit of work accomplished.

To overcome these objectionable features it was finally decided to make the borings and secure the soundings from the drill boat employed on the work, as the work progressed, and not to require the removal of the overlying material before drilling and blasting the ledge rock. The method followed was, to some extent, governed by the conditions which controlled the movements of the drill boat. The currents here being practically parallel with the axis of the channel and also very strong, the boat was necessarily placed in position fore and aft parallel to this axis, progress being made by moving the boat across the channel, or area to be excavated, in moves of 10 feet each. The lines on which drilling was done were thus spaced 10 feet apart. The holes to be drilled were also spaced 10 feet apart on these lines.

The soundings and borings were taken at the points selected for drill holes, as nearly as practicable, by a leadsman under the di-

rection of an inspector, both of whom were in the employ of the United States. In starting the work for any cross section the drilling machine, whose beam measurement was 35 feet, was placed in position with its drilling side outside of the area to be deepened and the other side on the limiting line of this area. Soundings and borings were then taken on both sides of the hull until the drills reached this limiting line, when the latter were put in operation and the taking of soundings and borings was confined to the side of the hull opposite the drills. Since they were taken at each move of the drill boat, it follows that slope depths on the opposite side of the channel had been secured by the time the drills had completed work on the limiting line on that side. Also, since at least one measurement was taken at the ends of each line beyond the last hole to be drilled, the outside limits of the area covered by the soundings and borings were kept at a safe distance from the outside limits of the area likely to be disturbed by blasts.

Before commencing the actual work of drilling, tests were made to determine the practicability of utilizing measurements to ledge rock taken with the steel drill used by the contractor in his work. The results showed that depths secured in this way not only interfered with the contractor's operations, but were also greater than the true depths, the average of twenty-five measurements with the drill being 0.27 of a foot greater than a corresponding number of measurements with the steel pointed pole.

The work contracted for required the removal of about 24,000 cubic yards of ledge rock and about 8,000 cubic yards of overlying material from an area of approximately 26,500 square yards in extent. This work is now nearly completed. All measurements for the determination of volumes have been taken, using the method described in paragraphs 4 and 5 preceding, at a considerable saving in cost to the United States, and the measurements thus secured gave results at least as accurate as those secured by the method followed heretofore.

While it has been demonstrated that satisfactory results may be expected by the use of this method of measurement when the overlying material is of a character not likely to be disturbed by the blasting of the underlying rock, to such extent as to shift in position and form shoals in adjacent areas, it may seem improbable that like results may be obtained in localities where the overlying material is easily disturbed as, for example, soft mud or loose sand; but decision as to the method to be adopted should be made only after a careful investigation of the governing factors has been concluded. It is reasonable to expect favorable results when the covering layer consists of clay, stiff mud, gravel, or hard pan; on the other hand, when this covering layer consists of soft mud, loose sand, or other like material, the thickness of this layer, its position with respect to adjacent waters, the strength of currents, and other local conditions, as well as the requirements of the work, may govern, to a considerable extent, the choice of the method of measurement to be adopted.

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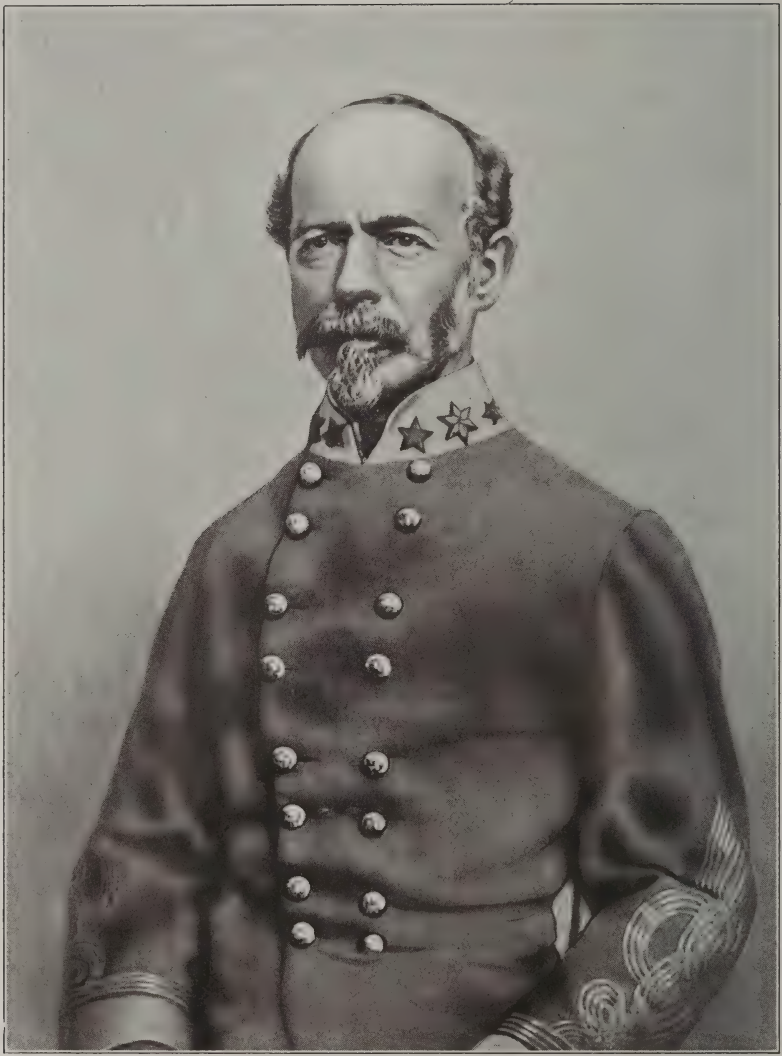


JOSEPH EGGLESTON JOHNSTON.

Born February 3, 1807.

Cadet, U. S. M. A., 1825-1829.
Second Lieutenant, Fourth Artillery, 1829.
First Lieutenant, Fourth Artillery, 1836.
Resigned, 1837.
First Lieutenant, Topographical Engineers, 1838.
Brevet Captain, 1838.
Captain, Topographical Engineers, 1846.
Brevet Major, 1847.
Lieutenant Colonel, Voltigeurs, 1847.
Brevet Colonel, 1847.
Lieutenant Colonel, First Cavalry, 1855.
Brigadier General, Staff (Q. M. General, U. S. A.), 1860.
Resigned, 1861.
Major General, C. S. A., 1861.
General, C. S. A., 1861.

Died, 1891.

Filling and Emptying the Third Lock at St. Marys Falls Canal, Michigan.

BY

Mr. L. C. SABIN,
Assistant Engineer.

In a lock designed to pass vessels from one level to another, the required size of the sluice or valve opening through which the lock is filled to communicate with the upper level, or emptied to communicate with the lower level, depends upon the size of the lock chamber, the difference in level, and the period of time in which it is desirable to fill or empty the lock. The size of the lock chamber is determined by the character of vessels and volume of traffic, but the time allowable for a single operation depends on the number of lockages that must be made within a given period.

In a general way, it may be said that in locks in service the usual ratio of the horizontal cross section of the lock chamber to the cross sectional area of the valve and culvert openings is between 200 and 300, although there are many cases where this ratio is outside of these limits, values as low as 140 and as high as 370 being found.

At St. Marys Falls Canal the volume of the traffic is such that the lockage facilities are at times taxed to the utmost. In the year 1915 there passed through the largest lock over 57 million tons of freight during the season of navigation, more than 54 million tons of which passed in the seven months of May to November, inclusive, or at the rate of 255,000 tons per day through one lock. The number of vessel passages through this lock in the same time was 7,621, or at the rate of over 35 vessels per day, with an average cargo of over 7,000 tons each. Because of the congested traffic conditions it was desirable, in the design of the Third Lock,

[NOTE: An article by Mr. Sabin, entitled "Fluctuations of Water Level in a Canal Caused by the Filling of Locks," was printed in PROFESSIONAL MEMOIRS, No. 10, Vol. 3 (April-June, 1911).—ED.]

to provide for filling and emptying the lock as quickly as it would be safe to raise or lower a boat. The Poe Lock, the largest one then in use, could be filled in about eight or nine minutes with about 1 square foot of culvert area to each 300 square feet of horizontal cross section of lock chamber. The Third Lock being about 600 feet longer, it was anticipated that more difficulty would be experienced in so distributing the water entering the lock as not to cause the vessel to surge back and forth in the chamber, and that on this account it might not be practicable to allow the new lock to fill as rapidly as the Poe.

When the connection between the lock and the upper or lower level is through a submerged orifice, the law of flow is such that the lock is three-quarters filled or emptied in one-half the time required to completely equalize the levels. That is, for a constant area of submerged opening, and constant levels of the upper and lower pools, the average rate of flow throughout the first half of the time required to equalize is three times the average rate throughout the last half of the time. The last foot or so is equalized very slowly under the low head. To increase the area of the opening during the latter part of the period of filling or emptying will thus have a marked effect on the total time required to equalize. It was decided, therefore, to provide ample valve and culvert capacities in order that a large area might be available for discharge after the head should be somewhat reduced, even though it might be found impracticable to open all of the valves while the head remained high.

The plan adopted is shown on Plate I. There are six filling culverts under the floor, each having a cross sectional area of about 88 square feet. The valves at the head of the culverts are 9 by 12 feet, with clear opening of about 90 square feet. The four inner culverts extend the entire length of the lock, while the outside culverts extend only about half way. The outside culverts are made shorter to save expense, and, as the valves in these culverts are opened after the head is somewhat reduced, the distribution of inflow is sufficiently good. All of the culverts have ports and manholes through the floor to communicate with the chamber. Each of the culverts has a large manhole at the lower end, 2 by 9 feet in size. Each of the inner pair has 59 ports, 1 foot by 3 feet in cross section. The next pair has the same number of ports with an additional manhole, 2 by 2 feet. Each of the outside pair has 40 ports,

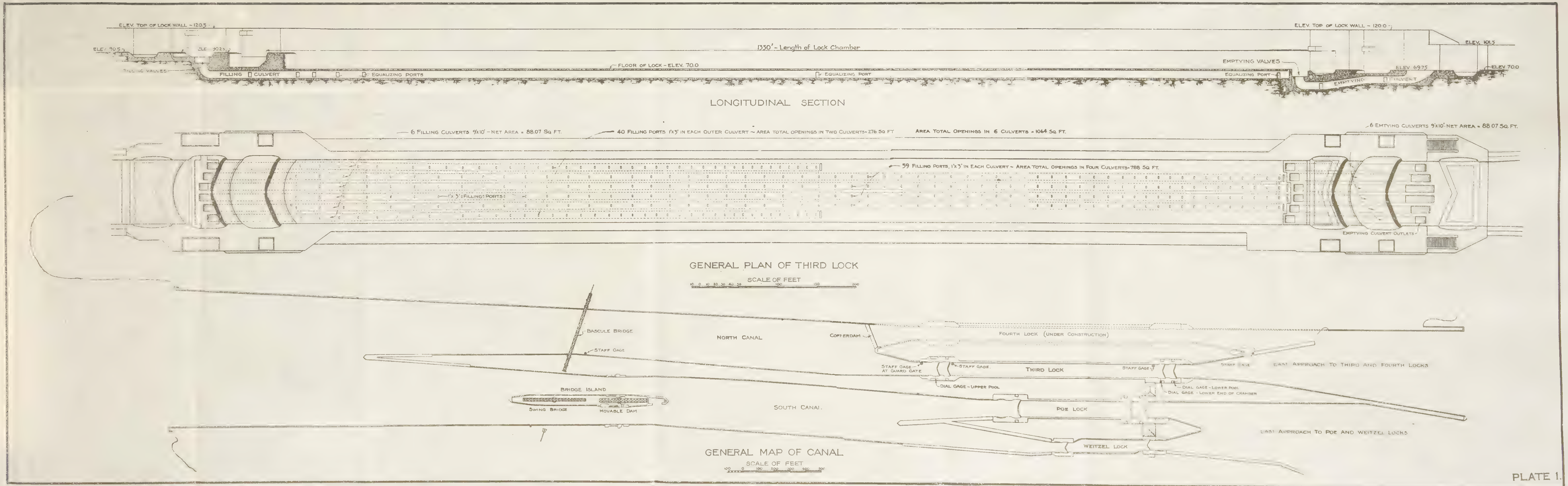

ELEV. TOP OF LOCK WALL ~ 120.5
1350' ~ Length of Lock Chamber
ELEV. TOP OF LOCK WALL ~ 120.0
ELEV. 101.5
FLOOR OF LOCK ~ ELEV. 70.0
FILLING CULVERT
EQUALIZING PORTS
EQUALIZING PORT
EMPTYING VALVES
ELEV. 69.75
ELEV. 70.0
LONGITUDINAL SECTION
6 FILLING CULVERTS 9'x10' ~ NET AREA = 88.07 SQ. FT.
40 FILLING PORTS 1'x3' IN EACH OUTER CULVERT ~ AREA TOTAL OPENINGS IN TWO CULVERTS = 276 SQ. FT.
AREA TOTAL OPENINGS IN 6 CULVERTS = 1064 SQ. FT.
6 EMTYING CULVERTS 9'x10' NET AREA = 88.07 SQ. FT.
59 FILLING PORTS, 1'x3' IN EACH CULVERT ~ AREA TOTAL OPENINGS IN FOUR CULVERTS = 788 SQ. FT.
1'x3' FILLING PORTS
EMPTYING CULVERT OUTLETS
GENERAL PLAN OF THIRD LOCK
SCALE OF FEET
BASCULE BRIDGE
STAFF GAGE
NORTH CANAL
COFFERDAM
FOURTH LOCK (UNDER CONSTRUCTION)
STAFF GAGE AT GUARD GATE
STAFF GAGE
THIRD LOCK
EAST APPROACH TO THIRD AND FOURTH LOCKS
DIAL GAGE ~ UPPER POOL
DIAL GAGE ~ LOWER POOL
DIAL GAGE ~ LOWER END OF CHAMBER
BRIDGE ISLAND
SWING BRIDGE
MOVABLE DAM
SOUTH CANAL
POE LOCK
EAST APPROACH TO POE AND WEITZEL LOCKS
WEITZEL LOCK
GENERAL MAP OF CANAL
SCALE OF FEET

PLATE 1.

1 foot by 3 feet. The total area of the openings through the floor for the several culverts is thus as follows:

Inner pair,	195 square feet, each, or	390 square feet
Intermediate pair,	199 square feet, each, or	398 square feet
Outside pair,	138 square feet, each, or	276 square feet
Total		1,064 square feet

The several culverts also communicate with the adjacent ones by large openings through the vertical walls separating them, these openings being about 28 square feet in cross section. The outer culverts communicate with the adjoining ones through six of these openings, and the others communicate with each other through seven openings. The effect of this is to distribute the flow throughout all the culverts, even though all of the valves may not be open, thus giving better distribution of flow as well as relieving the horizontal pressure on the side walls.

In the emptying culverts there is no attempt at distribution; the water is all drawn from the valve well or pit just above the lower gates and flows through the culverts under the two lower miter walls, discharging into the lower pool. As the valves are operated this results in a mean velocity in the vertical cross section of the lock chamber, near the lower end, of about 3 1-3 feet per second as a maximum when a down lockage is in progress. There is no trouble in holding a vessel in position with this velocity, the only inconvenience being that in case the bow is so close to the lower gate as to be over the whirl or vortex that forms over the valve pit, the bow is sometimes drawn away from the lock wall.

On several occasions tests have been made to determine the rate of filling and emptying the lock with 2, 4 and 6 valves open, and thus deduce the discharge coefficient, the methods used being as follows: On two days when it was desired to determine the difference in level at the two ends of the lock chamber at the same instant, a level rod was secured in an upright position on a scow, and readings on the rod taken with an engineer's level set up on the lock wall. Two scows were used, one at each end of the chamber, and two level observers took readings on flag signals given at half-minute intervals. On the other days when observations were taken, the elevations of water surface in the chamber were read from long gage boards or level rods fastened to the lock walls, the gage readers being stationed in small boats close to the rods. The latter method was considered sufficiently accurate for determinations of time of

filling and emptying, since small errors in individual readings would have practically no effect on the final results. The elevations of upper and lower pools were usually taken with staff gages, though sometimes dial gages were read. In all cases the one directing the tests kept the time, made general notes, and gave the necessary flag or whistle signals at half-minute intervals.

The locations of the several gages used are indicated on the map, Plate I. At the upper end the inlet to the dial gage is in the pipe shaft leading to the valve well. When the valves are open the water in the well is drawn down by the current, so that

this gage indicates only the local condition immediately over the valves. For determining the head, therefore, the gage at the guard gate at the head of the lock was used and the local effect at the valves disregarded. Likewise, in emptying, the level immediately below the lock is raised momentarily, but as soon as the flow is established the level is materially reduced, so that in this case the gage located 400 feet below the lock was considered to indicate the level of the pool into which the culverts discharged. Thus these purely local effects, at the inlets of the filling culverts and the outlets of the emptying culverts, were considered incident to the culvert system, and covered by the resulting values of the co-

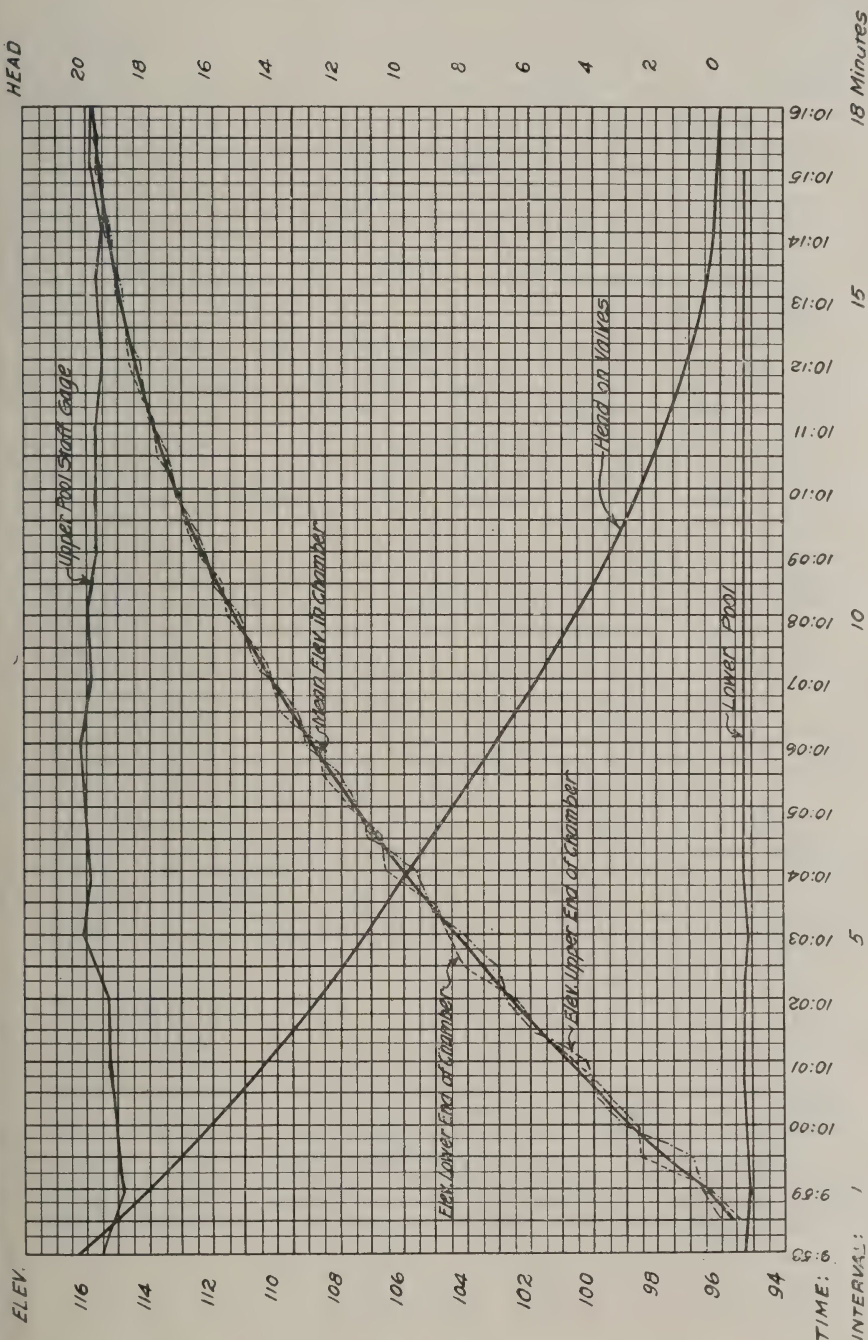


Plate II. Third Lock. Filling, 2 valves. December 4, 1914.

efficient of discharge. Had the levels immediately at the inlets and outlets been used in the reductions, the value of the derived coefficient would have been greater for the filling culverts and less for the emptying culverts.

The formula for discharge under decreasing head is

$$t=\frac{2A}{Ma\sqrt{2g}}(\sqrt{H_o}-\sqrt{H_n}) \qquad \text{(Eq. 1)}$$

in which A is the horizontal cross section of the vessel being filled or emptied, in this case the lock.

a is the area of cross section of the opening or valves in use;
M is the coefficient of flow, a constant depending on the discharge conditions;
g is the acceleration of gravity, and
t is the time in seconds required to change the level from initial head H_o to the final head H_n, the latter being zero when the levels are equalized.

The above formula is applicable only when the change in head is that due solely to the filling or emptying of the vessel; that is, it presupposes a constant level of the pool from which the lock is filled or into which it is emptied. When there is a canal or channel of moderate size leading to or away from the lock, as is the case in this instance, the level just above or below the lock is not constant. As this affects the head acting on the water entering or leaving the lock, the formula is not strictly applicable, and, if used, would give an incorrect value of the coefficient of discharge.

If six valves at the upper end are opened suddenly to fill the lock, the level in the canal immediately above the lock will drop 2 feet while the level in the chamber is rising 3 feet, so that the head on the valves is decreased 5 feet within about one minute after the valves are opened. A little later the level outside starts up and continues to rise slowly until the lock is full, so that the head is continuously less than it would have been had the level of the upper pool not been affected. In emptying, the first effect of the flow is to raise the lower pool, but as soon as the current is established it falls below normal; immediately below the lock it remains below normal until the lock is emptied, but a little farther downstream it regains normal level more quickly. The effect on the level of the lower pool, however, is much less marked and not so uniform as in the case of the upper pool.

By dividing the time of filling into short periods, the mean

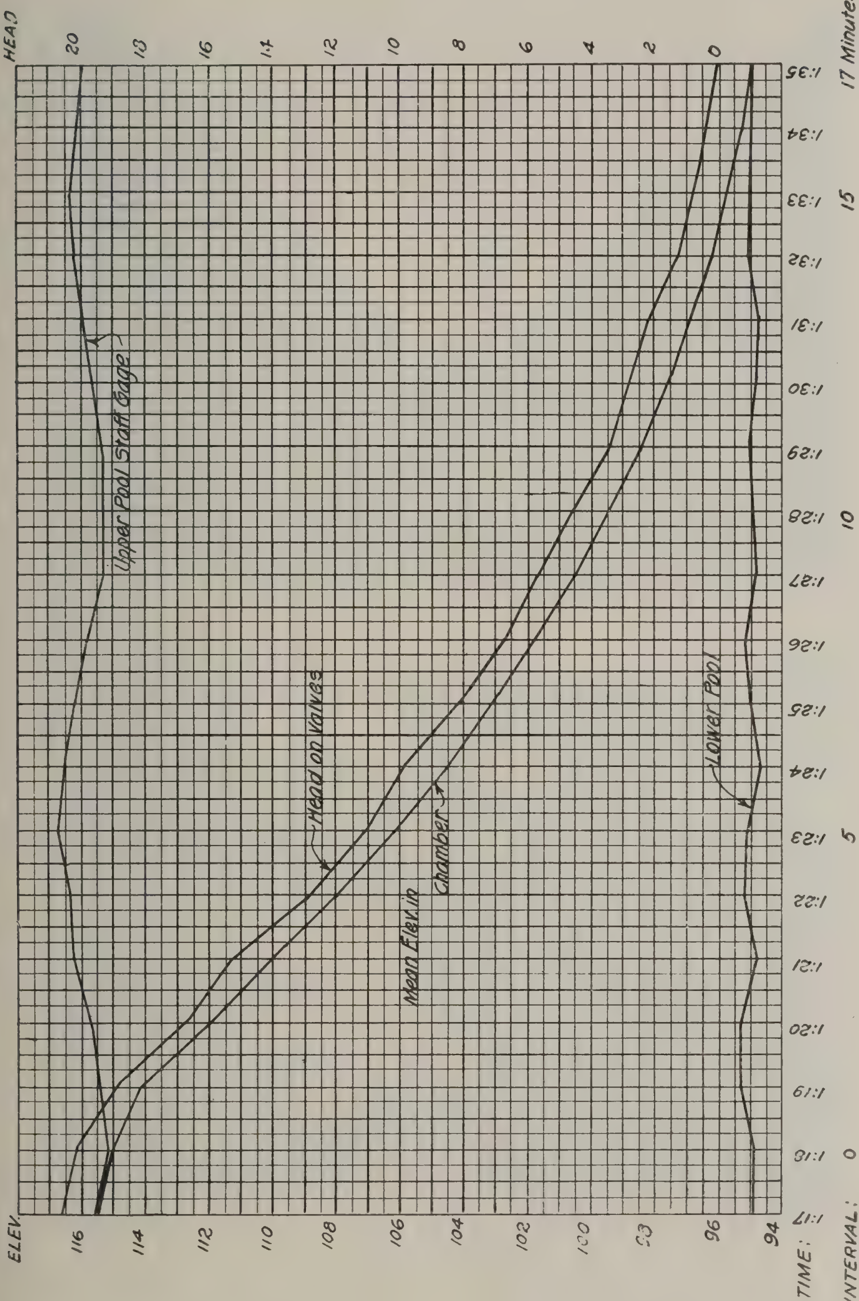


Plate III. Third Lock. Emptying, 2 valves. June 15, 1915.

View in Third Lock Chamber. Looking west. Unwatered October 20, 1915.

Third Lock Machinery. Upper filling valves and engines in place. View looking northwest.

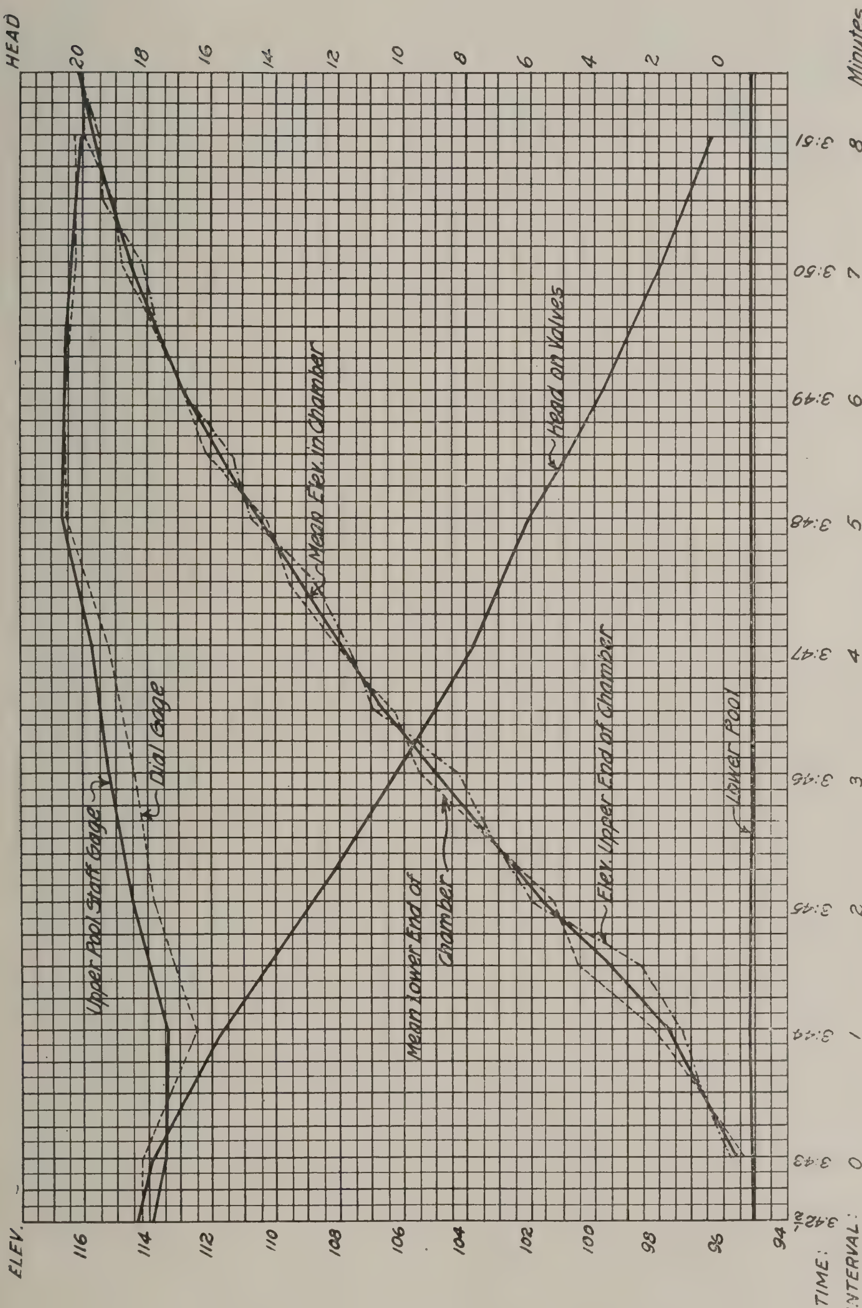


Plate IV. Third Lock. Filling, 4 valves. December 4, 1914.

velocity may be assumed, without appreciable error, to be a function of the mean head derived by taking the mean of the initial and final heads for this short period. If h represents such a mean, $v=m\sqrt{2gh}$. If A is the horizontal cross sectional area of the lock chamber, a the cross sectional area of the culverts in use, and D= change in level of the lock chamber during the period, then

$$vta=AD$$

and

$$t=\frac{AD}{am\sqrt{2gh}}$$

or

$$m=\frac{AD}{at\sqrt{2gh}}=\frac{A}{a\sqrt{2g}}\cdot\frac{D}{t\sqrt{h}}=\frac{KD}{t\sqrt{h}} \qquad \text{(Eq. 2)}$$

where

$$K=\frac{A}{a\sqrt{2g}}$$

For this lock the value of K is as follows:

With 2 valves open, K=86.
With 4 valves open, K=43.
With 6 valves open, K=28.67.

On Plates II to VII are plotted individual observations of the time of filling and emptying the lock with 2, 4 and 6 valves. As already pointed out, it will be noticed from the diagrams that the head on the valves throughout the filling is reduced by the variation in level of the upper pool. In emptying, the head is at first reduced; but in the latter part of the emptying, the lower pool level being restored, the change in head is practically that resulting from the lowering of the water in the chamber.

In Table No. 1 are given the results of the observations of rate of filling the lock with 4 valves, and an illustration of the method of deriving the value of m in the formula (Eq. 2), $m=\frac{KD}{t\sqrt{h}}$ where in this case K=43 and t=60. The mean value of m derived by this method is .73. It will be noticed from Plate IV that the filling of the lock happens to start at a low stage of the upper pool. In consequence of this, the formula (Eq. 1) $t=\frac{2A}{ma\sqrt{2g}}(\sqrt{H_o}-\sqrt{H_n})$ gives nearly the same result:

$H_o=17.91$, $\sqrt{H_o}=4.23$, $H_n=0$, $K=\frac{A}{a\sqrt{2g}}=43$, $t=3:51-3:43=$ 8 minutes=480 seconds, and $m=\frac{2\times43\times4.23}{480}=.76$.

TABLE 1.—*Observed Time of Filling Lock with 4 Valves Open and Deduced Coefficient of Flow, M.*

Time P. M.	Water Levels—Elevations Above Canal Datum in Feet.					Head on Valves (2 - 6)	Change in Depth D (from 6)	Mean Head, h (from 7)	$\frac{D}{t\sqrt{h}}$ ($t=60$)	$M = \frac{43\ D}{t\sqrt{h}}$
	Upper Pool Staff Gage.	Upper End Lock Chamber.	Lower End Lock Chamber.	Lower Pool.	Mean Lock Chamber.					
1	2	3	4	5	6	7	8	9	10	11
3.42	114.35	95.43	95.66	95.0	95.54	18.81				
							.05	18.36		
3.43	113.50	95.79	95.39	95.1	95.59	17.91				
	Valves Opened						2.15	16.81	(.0087)	
3.44	113.45	97.30	98.18	95.2	97.74	15.71				
							3.91	14.28	.0173	.744
3.45	114.50	102.01	101.29	95.1	101.65	12.85				
							3.23	11.58	.0159	.684
3.46	115.20	104.28	105.49	95.1	104.88	10.32				
							3.01	9.09	.0167	.718
3.47	115.75	107.72	108.07	95.1	107.89	7.86				
							2.61	7.00	.0164	.705
3.48	116.65	110.73	110.27	95.1	110.50	6.15				
							2.33	4.96	.0174	.748
3.49	116.60	112.85	112.81	95.1	112.83	3.77				
							1.62	2.86	.0160	.688
3.50	116.40	114.16	114.74	95.1	114.45	1.95				
							1.23	1.16	.0190	.817
3.51	116.05	115.46	115.90	95.1	115.68	.37				
	Upper Gates Broke Miter									
	Mean Value M									.729

Plate VI shows the usual condition when filling with six valves and starting from a higher level, the upper pool being first drawn down 2 or 3 feet, and then slowly rising until the lock is filled. Equation 1 is not applicable to these conditions. If used, $H_0=19.07$, $\sqrt{H_0}=4.37$, $H_n=0$, $K=\frac{A}{a\sqrt{2g}}=28.67$, $t=3:20-3:13=7$ minutes$=420$ seconds, giving value of $m=\frac{2\times 28.67\times 4.37}{420}=.60$. This low and incorrect value is partly accounted for by the fact that some time is consumed in opening the valves. By dividing the time into short periods, taking the actual head for each, and using only those observations taken after the valves are fully opened, after the method illustrated in Table 1, gives a mean value of $\frac{D}{t\sqrt{h}}=.0252$, and $m=.73$.

As a result of seventeen separate observations, the following mean values of m were obtained:

Filling 2 valves, .73;
Filling 4 valves, .74;
Filling 6 valves, .75;
Emptying 2 valves, .72;
Emptying 4 valves, .79;
Emptying 6 valves, .83.

It will be observed that the spacing of the ports opening into the chamber from the culverts diminishes toward the lower end, the distance between the ports of each culvert being at the lower end of the culvert only one-half the distance between consecutive ports at the upper end. The object is to distribute the flow into the chamber as uniformly as possible and reduce the longitudinal current in the chamber itself.

On some of the plates the elevations of water surface at both ends of the lock are shown, and it is seen that when 4 or 6 valves are opened suddenly there may be a difference in level at the two ends of as much as 2 feet. When the valves are open, the upper end of the chamber begins to rise first in filling and the lower end to fall first in emptying. This effect in filling might be considered to indicate that the variation in spacing of the ports should be still greater, but it is not at all certain that this is the case. At the instant the filling valves are opened the water at the upper end of the culvert may escape through the ports near the upper end or flow along the culvert horizontally to escape through ports farther down. As the water in the culvert must be set in motion, it is

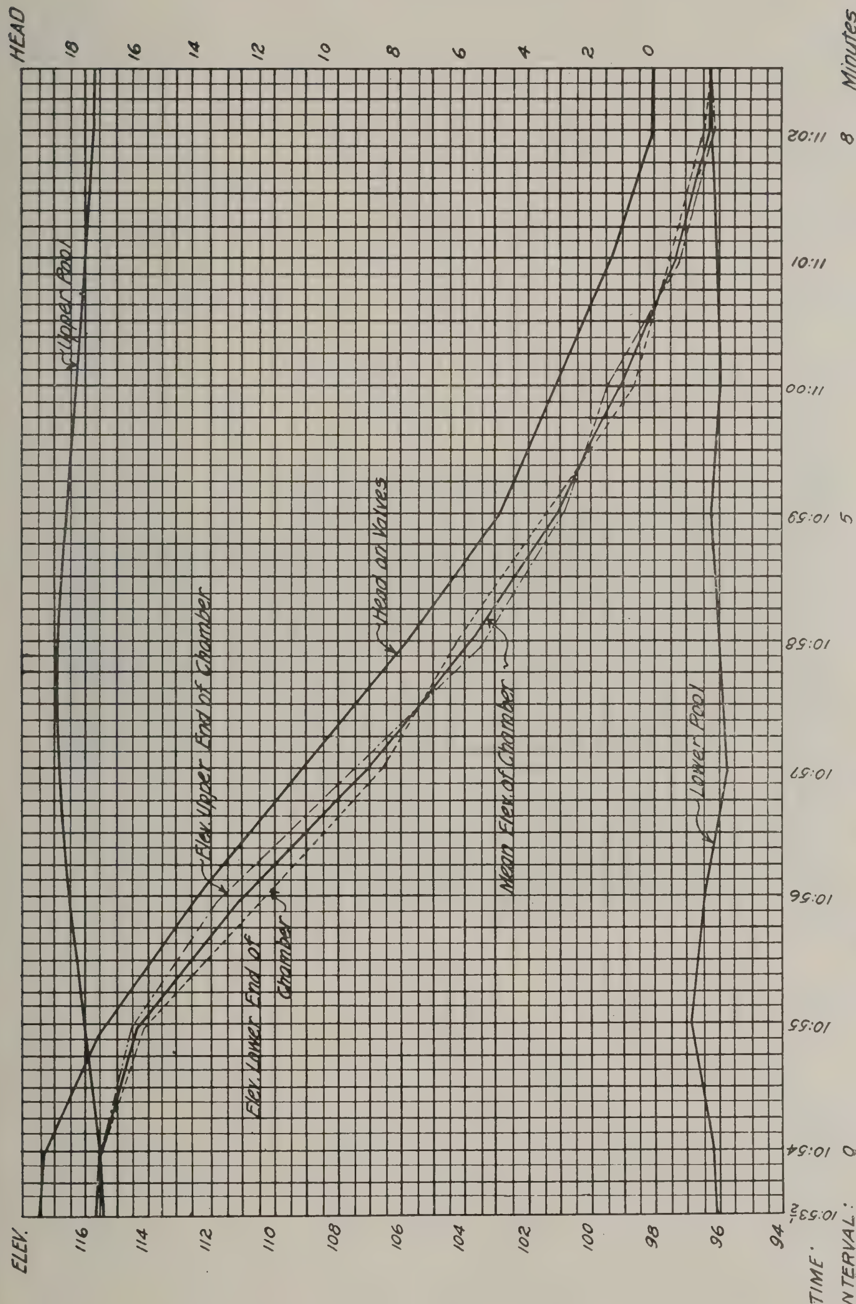


Plate V. Third Lock, Emptying, 4 valves. October 20, 1914.

natural that at first the discharge through the upper ports will be high, but this tendency will be overcome as soon as flow is established, and the results on the whole do not indicate that a change in spacing is desirable.

The extreme differences occur only when more than two valves are opened quickly, and the rate of flow is thus high. In order to prevent undue surging of the vessels in the lock, the second pair of valves is opened $2\frac{1}{2}$ to 3 minutes after the first, and the third pair after about the same interval, so that, under the conditions of operation when vessels are in the lock, the six valves are not open

Filling Third Lock with Six Culverts. Looking Upstream from side wall after valves open about 3 minutes. December 12, 1916.

until about 6 minutes after beginning the filling or emptying.

It is found that if the rate of rise or fall does not exceed about 4 feet per minute, no difficulty is experienced. Table 2 shows a schedule of operation to accomplish this result. The rate of filling used in determining this schedule is based on a mean value of m of .75, and with the assumption that the upper or lower pool level remains constant. Column 2 shows the time in minutes required to fill or empty the lock from the normal initial head of 20 feet to the head opposite in column 1. That is, under these assumptions, with two valves it requires 5.01 minutes to fill or

TABLE 2.—*Time to Fill or Empty Lock, Assuming Constant Level Upper and Lower Pools and Mean Value M = .75.*

Head	Σt or Time in Minutes to Fill or Empty from 20-foot Head to Head in Column 1, Assuming M = .75.			Δt or Time in Minutes to Fill or Empty Each Foot			Σt Using 2 to 6 Valves and Confining Rate of Rise to 4 Feet per Minute			Corresponding Rate of Rise per Minute
	2 Valves Minutes	4 Valves Minutes	6 Valves Minutes	2 Valves Minutes	4 Valves Minutes	6 Valves Minutes	2 Valves Minutes	4 Valves Minutes	6 Valves Minutes	Feet.
1	2	3	4	5	6	7	8	9	10	11
20	.000	.000	.000							
19	.432	.216	.144	.432			.432			2.32
18	.875	.438	292	.443			.875			2.26
17	1.334	.667	.445	.459			1.334			2.18
16	1.804	.902	.601	.470			1.804			2.13
15	2.289	1.145	.763	.485	(.243)		2.289			2.06
14	2.789	1.395	.930	(.500)	.250			2.539		4.00
13	3.31	1.655	1.103		.260			2.799		3.85
12	3.85	1.925	1.283		.270			3.069		3.70
11	4.41	2.205	1.470		.280			3.349		3.57
10	5.01	2.505	1.670		.300			3.649		3.33
9	5.63	2.815	1.877		.310			3.959		3.23
8	6.28	3.140	2.093		.325	.216		4.284		3.08
7	6.98	3.490	2.327		.350	.234		4.634		2.86
6	7.73	3.865	2.577		(.375)	.250			4.884	4.00
5	8.55	4.275	2.850		(.410)	.273			5.157	3.66
4	9.45	4.725	3.150			.300			5.457	3.33
3	10.47	5.235	3.490			.340			5.797	2.94
2	11.69	5.845	3.900			.410			6.207	2.44
1	13.26	6.630	4.420			.520			6.727	1.92
0	17.10	8.550	5.700			1.280			8.007	.78

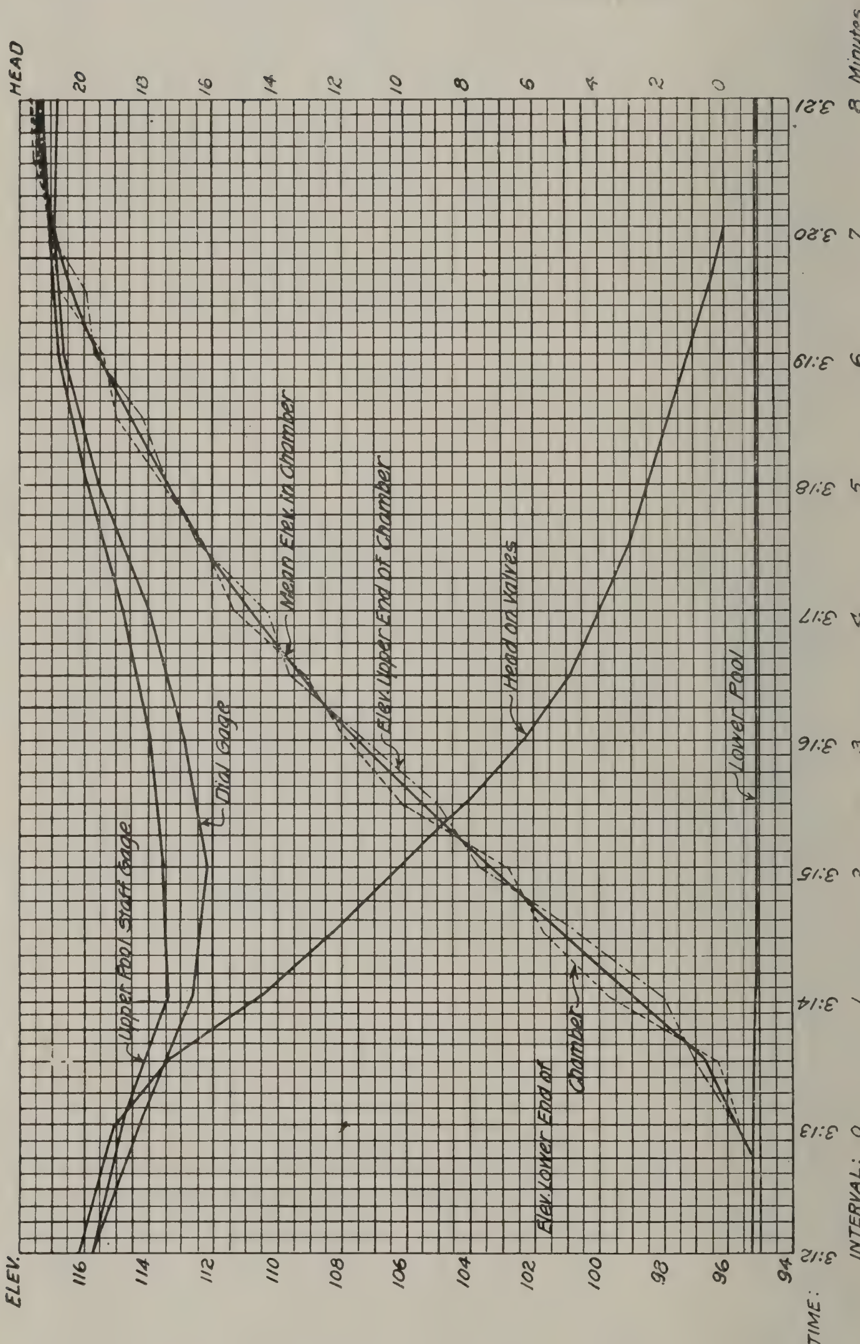


Plate VI. Third Lock. Filling, 6 valves. December 4, 1916.

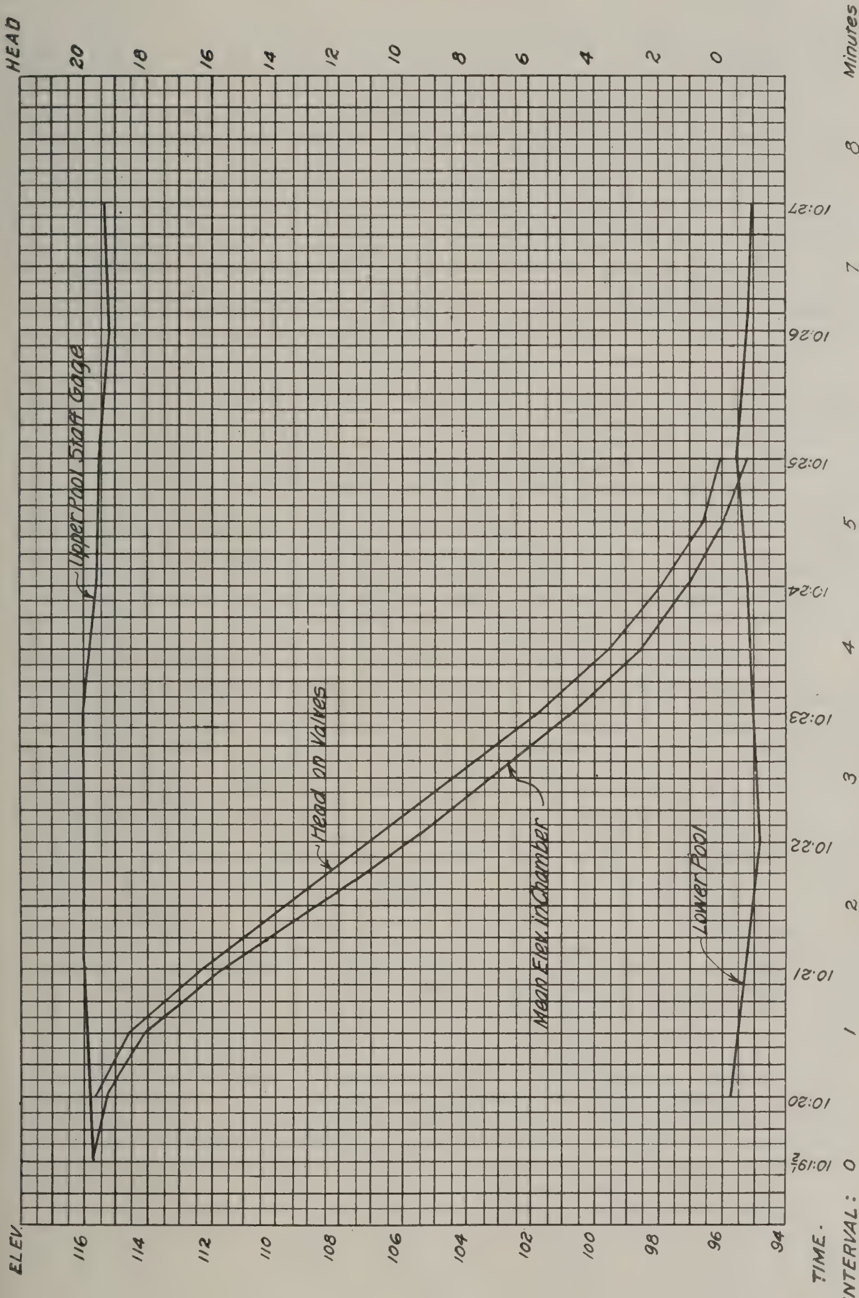


Plate VII. Third Lock. Emptying, 6 valves. December 4, 1914.

empty the lock 10 feet, or from a head of 20 feet to a head of 10 feet, and 17.1 minutes to fill or empty the entire 20 feet, or from head of 20 feet to head zero. Columns 3 and 4 show the corresponding times for 4 and 6 valves, respectively. Column 5 shows the differential of time for each foot filled with two valves, and is derived directly from column 2; that is, to fill or empty from head of 17 feet to head of 16 feet requires 1.804—1.334, or .47 minute. Columns 6 and 7 show similar differentials for 4 and 6 valves open. Columns 8, 9 and 10 show the total time required to fill the lock from 20-foot head to the head opposite in column 1 under the following conditions: 2 valves in use until the head is reduced to 15 feet, then 4 valves in use until the head is reduced to 7 feet, and then 6 valves open until the levels are equalized. The rate of filling under this arrangement is shown in column 11, and it is seen that the rate of 4 feet per minute is not exceeded at any time. The total time of filling or emptying appears in column 10 as about 8 minutes. In actual operation, as already stated, the opening of successive pairs of valves is separated by 2½ to 3 minutes, and the pool levels are not constant; in consequence, a little longer time than 8 minutes is usually required to equalize.

One of the points which it was desired to bring out in the tests was to determine the effect on the water level and current in the approaches during the operation. In some of the observations made December 4, 1914, the valves were opened as quickly as possible, in order to give as great an effect on the water level as possible. Some of these observations are shown on Plate VIII. The most pronounced effect, of course, occurs when six valves are opened suddenly. It is seen that the level of the upper pool at the guard gate may have an extreme range of nearly 4 feet under these conditions; in emptying, the lower pool may have a range of over 1½ feet. The difference in the effect is due to the more restricted channel of the upper approach. The amplitude of the wave in the upper canal at a point 2,000 feet west of the lock is less than 3 feet under extreme conditions. The time interval between successive high stages is about 9 1-3 minutes. Similar observations in the south canal leading to the Poe Lock indicated an interval of 12 to 13 minutes.

Taking the observations shown on Plate VI for filling the locks with six valves between 3.12 and 3.20, the elevation in the lock at 3.12 was 95.2, and of upper pool 115.7; at 3.15 it was 103.3 in the lock, 113.5 above the lock, and 114.3 at a point 2,000 feet farther

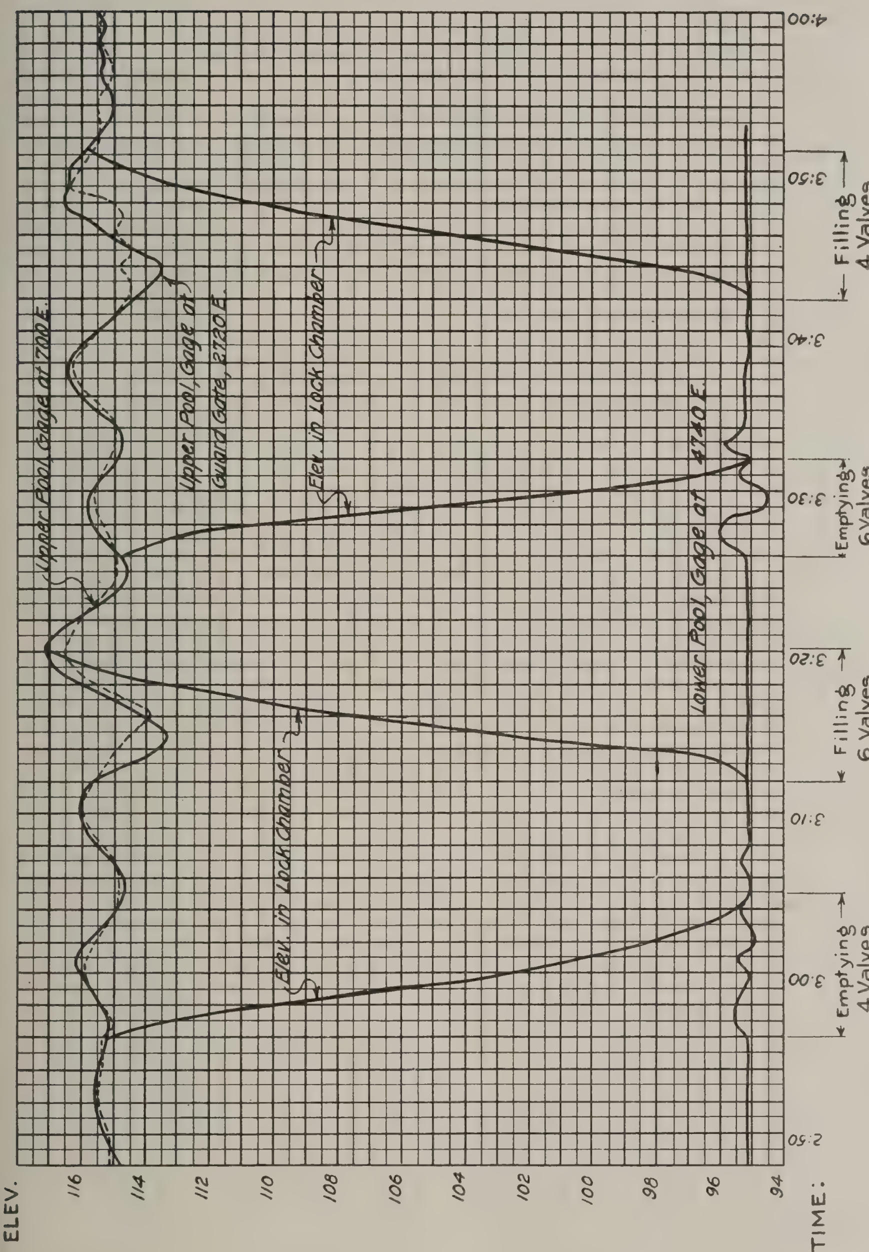


Plate VIII. Third Lock. Fluctuations in Levels—Upper and Lower Pools.

west; at 3.20 it was 117.0 in the lock and lower end of canal, while it was 116.6 in canal 2,000 feet west. At 3.12 the elevation of water surface in canal was receding, the current being upstream, as appears from the form of the upper curve. Between 3.12 and 3.15 about a million cubic feet of water was taken into the lock from the upper pool, while the stratum of water over the canal between the levels at 3.12 and 3.15 represents a loss in the canal of about one and a half million cubic feet. In other words, a million cubic feet flowed from the canal into the lock and a half million cubic feet flowed out of the canal at upper end. The trend of the flow near the upper end of canal thus continued in an upstream direction for some time after the valves were opened, although the current near the lower end of the canal was downstream. Between 3.15 and 3.20 the water level in the lock rose 8.1 feet, and in the canal from .8 to 2.2 feet, requiring nearly two and a half million cubic feet to fill the lock, and about one million seven hundred thousand cubic feet to raise the canal, giving a total of over four million cubic feet flowing into the canal at the upper end in five minutes, with an average velocity of 2.2 feet per second, or one and a half miles per hour. As there is ample room for navigation, this current in the canal results in no serious inconvenience, but to escape any effect of the current around the end of the pier it is necessary for boats entering the canal to keep at a reasonable distance from the center pier until well into the canal.

The Passes of the Mississippi River.

THEIR DESCRIPTION, PHYSICAL CHARACTERISTICS, DEVELOPMENT, AND COMMERCE.

BY

Lieut. Col. EDWARD H. SCHULZ,
Corps of Engineers.

GENERAL CONTENTS.

ACCOMPANYING PLATES.

[The author of this memoir was in charge of improvements of Southwest and South Passes, Mississippi River, at the time it was written.]

*Not printed.

†Printed in Report of Chief of Engineers, U. S. Army, for 1916 (Vol. 2, page 2426).

1. *General description.* The watershed of the Mississippi River comprises about 1,240,000 square miles, being about 41 per cent of the area of the United States proper. The watersheds of the principal tributaries are as follows:

	Square miles.	Per cent.
Mississippi, above mouth of Missouri	165,900	13
Missouri	527,150	43
Ohio	201,700	16
Arkansas	186,300	15
Middle and Lower Mississippi	69,000	6
Red	90,000	7
Total	1,240,050	100

The maximum discharge of the river at Carrollton (New Orleans) was on May 11, 1912, and amounted to 1,309,818 cubic feet per second, with the gauge of 20.7 (zero of Carrollton gauge is 0.13 below mean Gulf level). The average low-water discharge with Carrollton gauge at 2 feet is about 100,000 cubic feet per second.

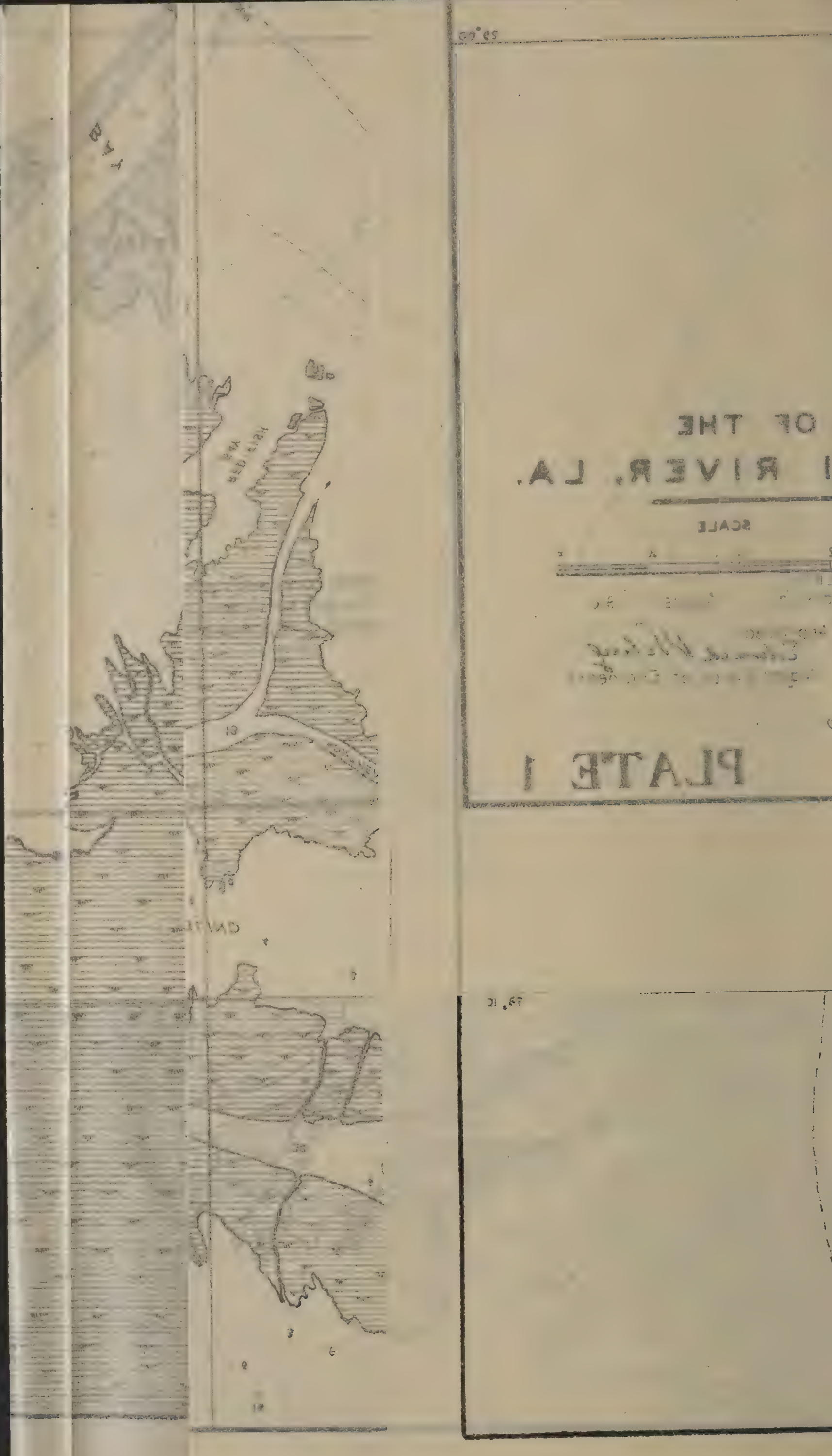
New Orleans is situated 94½ miles above Head of Passes, or 114 miles above the Gulf by Southwest Pass and 108½ miles above the Gulf by South Pass. The distance from New Orleans to important points on the tributaries are: Pittsburg on the Ohio, 1,933 miles; St. Paul on Upper Mississippi, 1,838 miles; Kansas City on the Missouri, 1,554 miles; Fort Benton on the Upper Missouri, 3,447 miles; Wichita on the Arkansas, 1,333 miles; Shreveport on the Red River, 509 miles.

The uppermost outlet of the Mississippi is the Old, or Atchafalaya, River (also an outlet of the Red River), on the right bank, about 296 miles above Head of Passes. Coming downstream, the next outlet is The Jump, on the right bank, about 186 miles below Old River and 10½ miles above Head of Passes. Between Old River and The Jump there were formerly three outlets, as follows:

Bayou Manchac, left bank, 212 miles above Head of Passes; closed by a dam in 1828;

Bayou Plaquemine, right bank, 206 miles above Head of Passes; closed by a dam in 1867 and opened to navigation in 1909 by a lock 55 feet wide, 260 feet long, and 10 feet deep over miter.

Bayou Lafourche, right bank, 174 miles above Head of Passes; closed in 1904 by a dam.




PASSES OF THE
MISSISSIPPI RIVER, LA.
IN 1-SHEET
SCALE
MILES
To accompany memoir on Passes of the
Mississippi River dated August
By Major Edward H. Schulz, Corps of Engineers
Submitted
Approved
Major, Corps of Engineers
PLATE 1
Chart of Prevailing Winds F.Y. 1916.
Indicates 5 to 9 Miles per hour
10 to 14
15 to 24
25 to 34
35 and over
N.
MISSISSIPPI RIVER
MAIN PASS
OCTAVE PASS
CUBITS GAP
RAPHAEL PASS
GRAND PASS
PADDY BAY
LOUTRE
NORTH PASS
JACKASS BAY
BLIND BAY
HEAD OF PASSES
UPPER DAM
WEST DIKE
HD. OF PASSES LT.
PASS
SOUTHEAST PASS
NORTHEAST PASS
RED FISH BAY
GARDEN ISLAND BAY
WHALE BAY
PORT EADS
SOUTH PASS LT.
COWHORN REEF
WEST BAY
EAST BAY
SOUTHWEST PASS
SOUTHWEST PASS LIGHT
BURRWOOD
WEST JETTY
EAST JETTY
30' CONTOUR
60' CONTOUR
120' CONTOUR
240' CONTOUR
LIGHTSHIP
29°10'
29°00'
89°25'
89°15'
89°05'

Below The Jump, or Grand Pass, is another outlet, known as Cubits Gap, on left bank, about 3½ miles above Head of Passes.

At Head of Passes begins the real division of the Mississippi River into three mouths—Pass a Loutre, South Pass, and Southwest Pass. All of these entrances have at times been used for commerce, and have been the subject of contemplated improvement. Only the South and Southwest Passes have been under improvement, and these two Passes are now both used for foreign and coastwise traffic of New Orleans. The location of the Passes is shown by Plate 1.

Southwest Pass is the westernmost of the mouths of the Mississippi River. (See U. S. Coast and Geodetic Survey chart No. 19.) Its length, from Head of Passes to the Gulf of Mexico, is 19½ miles. It flows in a generally southwest direction. Distance of outer end of Pass from New Orleans, La., is 114 statute miles; from Mobile, Ala., 160 statute miles; from Galveston, Tex., 330 statute miles. Average width is 2,000 feet; the narrowest section is 1,190 feet; widest section, 4,950 feet. It is a tidal stream, but about eight months of the year is influenced by river floods. During floods, the maximum fall is about 5 feet between the Head and Gulf. Average flood discharge, 355,000 cubic feet per second. Average discharge is 40.9 per cent of the water at Head of Passes.

South Pass, flowing south 32° east, is the smallest of the three main outlets of the Mississippi River. Its length, from Head of Passes to the Gulf of Mexico, is about 14 miles, and its average width is 700 feet. It is a tidal stream, but during about eight months each year the flow is chiefly influenced by river floods. With the crests of the floods, the fall is about 5 feet between the Head and Gulf, and South Pass discharges 125,000 cubic feet per second at flood stage. Its average discharge is 12 per cent of the river, or 14 per cent of the water which reaches Head of Passes. The entrance is 108½ miles from New Orleans, La.; 141 miles from Mobile, Ala.; and 349 miles from Galveston, Tex. (See U. S. Coast and Geodetic Survey chart No. 19.)

2. *History of improvements prior to adoption of present project.* (For detailed account, see Annual Report of the Chief of Engineers, U. S. Army, for 1915, page 1847.) The first appropriation for the improvement of the entrances to the Mississippi River was made in 1836, and this was followed in 1837 with a second appropriation. The two appropriations, amounting to $285,000, were expended

in an attempt to open Southwest Pass by using the ordinary bucket drag. No permanent improvement was effected.

A second attempt was made in 1852 to open Southwest Pass by stirring up the bottom. This work was done by contract with the Tow Boat Association, and a temporary channel 18 feet deep by 300 feet wide was obtained. This method, assisted later by dredging, was carried on until South Pass was opened to navigation by James B. Eads. A report by a board was also made in 1852, and recommended four methods: Stirring bottom; dredging; narrowing, revetting, and jettying; and, if these failed, a ship canal. As stated above, nothing except stirring was undertaken.

The 18-foot channel having disappeared, the sum of $330,000 was appropriated in 1856. A board was appointed, and recommended application of stirring the bottom and building the jetties at Southwest Pass and Pass a Loutre, and closing the other outlets. Work was undertaken in Southwest Pass by building a jetty 1 mile long on west side, but it was necessarily of light construction and did not last long. Stirring was continued intermittently, but the advent of the Civil War stopped all appropriations. In 1867, $200,000 was appropriated, and a powerful dredge was purchased to stir up and deflect sediment to the current. No great success was obtained.

In 1871 a board was appointed, which reported as feasible the construction of a canal from near Fort St. Philip to the Gulf, at a cost of over $10,000,000—the canal to be 27 by 200 feet and the lock to be 60 by 500 feet, by 25 feet over sill. A minority report was in favor of jetties.

Another board was appointed in 1875, which reported the cost of a canal at about $10,000,000, but recommended construction of jetties at South Pass, at an estimated cost of $5,342,000 and $130,000 per annum for maintenance, and at Southwest Pass at an estimated cost of $8,253,000 and $390,000 per annum for maintenance.

The channel maintained at Southwest Pass was inadequate to the needs of the port of New Orleans, and, after considerable controversy as to the advisability of improving the entrances to the river by jetties or by the construction of a lock and ship canal from the river at Fort St. Philip to the Gulf, the United States accepted, in 1875, the proposition of James B. Eads for the construction of jetties at South Pass, at a cost of $5,250,000, and in addition twenty years' maintenance, making a total of $8,000,000.

3. *Report of Board on Southwest Pass, appointed in 1898.* (See House Document No. 142, 55th Congress, 3rd session; also page 1863, Annual Report of Chief of Engineers for 1899.) On January 7, 1899, a report by a special board was made on the improvement of Southwest Pass. This board proposed the construction of parallel jetties from near East Point, on left bank of Pass, and from Stake Island on right bank of Pass, outward in prolongation of the channel to and beyond the crest of the bar, and in addition provided certain auxiliary works, including two dredges. The estimated cost was $13,000,000; cost of annual maintenance, 2 per cent of first cost, and an additional 1 per cent for future extension of jetties. The jetties were to be placed at a distance of 2,400 feet, center to center, and to extend seaward from East Point and Stake Island. From these points, the jetties were also to be extended inward or equivalent works (creosoted sheet pile or similar work) constructed to produce a corresponding width to a point where the natural width is about 2,400 feet. The natural banks of the Pass were also to be raised by levees, outlet bayous closed, and a sill placed across Pass a Loutre. The sea jetties were to be riprap stone on heavy foundation mattresses, the mattresses to be made of willows and to be about 3 feet thick and 150 feet wide. No part of jetty was to extend closer than 2,000 feet from end of mattress. Dredges were to assist in removal of material and guidance of current. The old sill at head of Southwest Pass was to be removed, and some dredging done in Pass proper.

The proposed length of sea jetties was 21,000 feet for East Jetty and 18,300 feet for West Jetty.

The proposed project was for a depth of 35 feet and adequate width, which, taken from the ideal section of about 2,400 feet between banks, was stated at about 900 feet.

No action on the above project was taken by Congress, other than appointing a new board (see below).

4. *Report of Board on Southwest Pass, appointed in 1899.* (See House Document No. 329, 56th Congress, 1st session; also page 2287, Annual Report of Chief of Engineers for 1900.) The Board of 1899 recomended a project to secure a channel 1,000 feet wide and 35 feet deep, by dredging; the construction of two sea jetties, sills across Cubits Gap, The Jump, and Baptiste Collets Canal; the closing of all minor outlets; the construction of a dredge and other plant; the purchase of land, etc.—the total estimated cost to

be $6,000,000 and $150,000 for annual maintenance. The board placed its main reliance on dredging, and depended on the jetties to assist and maintain the channel. The estimated yardage to secure the channel was 22,000,000 cubic yards, dredging to 38-foot depth. The purpose of the jetties was to protect the channel from injury by waves and to produce a scouring action to prevent its silting up. The jetties were to be built to the 20-foot contour on outer slope of bar, and, for ease and cheapness, to be placed in shallow water and not kept parallel—the inner ends to be about 7,000 feet apart and the outer ends 3,000 feet apart. The greater area between jetties was to afford dumping ground for dredged material. The height of jetties was limited to mean high tide. The jetties were to be of rock on foundation mattresses not less than 2 feet thick and 150 to 200 feet wide, surmounted by a timber grillage upon which was to be placed the superstructure of random stone, or preferably large concrete blocks. Inner jetties were not considered necessary. No scour along jetties, or racing of current, was anticipated, but estimate included a provision for protection of either one of jetties by spur dikes or continuous mattress. The entire work was to be completed in five years. The proposed length of sea jetties was 20,600 feet for East Jetty and 16,000 feet for West Jetty.

The project outlined in above report was adopted by Rivers and Harbors Act of June 30, 1902, subject to the provision that details of the work might be modified at the discretion of the Secretary of War.

5. *Present project for South Pass.* The present project for the improvement of South Pass was adopted in accordance with the Rivers and Harbors Act of March 3, 1875, amended by acts of June 9, 1878, and March 3, 1879, authorizing James B. Eads and associates to "construct such permanent and sufficient jetties and such auxiliary works as are necessary to create and permanently maintain a wide and deep channel between the South Pass of the Mississippi River and the Gulf of Mexico." This included securing and maintaining a channel 26 feet deep through the Pass and through the jetties at the mouth of the Pass, a channel 26 feet in depth and not less than 200 feet in width at the bottom, and having through it a central depth of 30 feet without regard to width. The channel was secured through the jetties July 8, 1879, and on that day began the period of twenty years' maintenance. The

period ended January 28, 1901, and the contract with Mr. James B. Eads and associates terminated. The emergency act of June 6, 1900, provided for maintaining by the United States, after termination of contract with Mr. Eads and associates, the channel secured, and appropriated $100,000 annually for this work. The Rivers and Harbors Act of May 28, 1908, authorized use of funds for this improvement to dredge a channel 35 feet deep (no width specified) through shoals in river between Cubits Gap and Head of Passes.

The total expenditures to June 30, 1916, on South Pass Improvement, amount to $9,880,108.59.

6. *Present project for Southwest Pass.* The present project (see paragraph 4 above) for the improvement of Southwest Pass, adopted by the Rivers and Harbors Act approved June 13, 1902, provides for securing, by dredging, a channel throughout Southwest Pass 1,000 feet wide and 35 feet deep at mean low water; the construction of jetties to protect the dredged channel at the mouth of the Pass; the closure of minor outlets; and the construction of sills to prevent the enlargement of the outlets of the river above the Pass; all at an estimated cost of $6,000,000 and $150,000 per annum for maintenance. The Act of 1902 provides that the details of the work may be modified at the direction of the Secretary of War. By the Act of May 28, 1908, dredging in the river at the Head of Passes and as far up as Cubits Gap, a distance of 3½ miles, was authorized whenever necessary to secure a depth of 35 feet, with practicable width. The total amount expended prior to the adoption of the present project was $921,043.01.

The project as carried out and authorized by the Secretary of War differed in detail from the report of the Board of 1899, in that the jetties were built to a height of 4 feet above mean high tide, and that they were located on straight converging lines to near the bar, then became parallel and crossed the bar with a width of 3,500 feet between them, whereas the Board of 1899 located the inner portion of the jetties along lines at first diverging and then converging and then bringing them sharply together to a distance of 3,000 feet and crossing the bar on parallel lines at this distance. The Board's plan contemplated a foundation mattress carrying a timber grillage upon which the concrete superstructure rested. This construction was modified, and the timber

grillage was abandoned for tiers of brush mattresses to bring the substructure to the water surface.

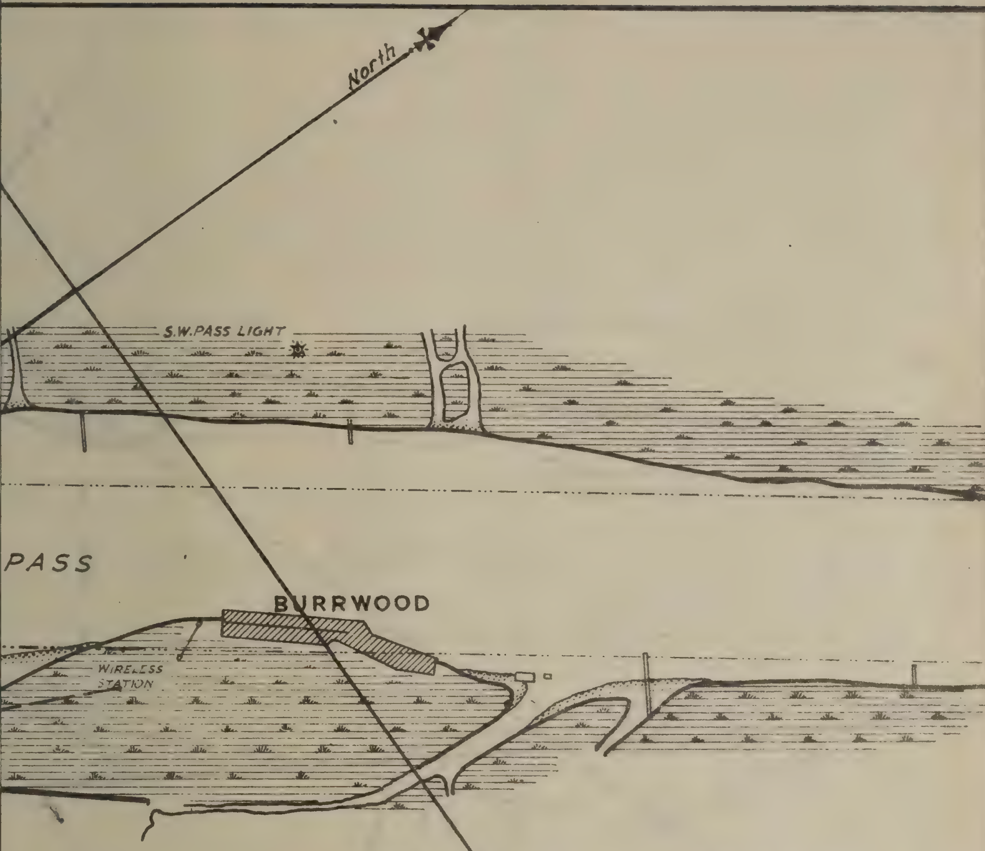
A comparison of projects of the Boards of 1898 and of 1899, and construction as carried out, is shown by Plate 2.

The amount expended on present project to June 30, 1916, has been $8,939,003.31.

7. *General consideration of physical conditions at the Passes.* The problem of obtaining and maintaining suitable channel depths across the bar at one of the mouths of a river carrying large amounts of sediment is one of the most difficult in hydraulic engineering. While it has been successfully solved at certain localities, at others it has failed. Where, as on the Mississippi, the attempt is made to maintain two independent channels, the difficulties are greatly increased.

A consideration of the necessary work to obtain a channel 35 feet by 1,000 feet through Southwest Pass must necessarily involve a thorough knowledge and study of the other two outlets, viz, Pass a Loutre and South Pass. This consideration must involve the discharge and regimen of the three passes; the currents in the passes; the Gulf currents at the mouths of the passes; the prevailing winds, storms and tidal conditions; sediment, deposits, mud lumps, and dredging; and a careful understanding of the results of the existing regulation work in South and Southwest Passes. From these considerations, the character and amount of work to secure a reasonably permanent channel in Southwest Pass may be determined.

8. *Cross-sections of the Passes and percentage of discharge.* The influence of the permanent works that have been constructed in connection with the improvement of South and Southwest Passes, on the flow of water through the three passes, is reflected in the relative cross-sectional areas and discharges through the outlets as shown by observations made about every six years. The following two tables give comparison of the three main outlets at Head of Passes:



MISSISSIPPI RIVER. LA.

SOUTHWEST PASS

COMPARATIVE JETTY PROJECTS

IN ONE SHEET — SCALE

2000' 0 2000' 4000' 6000'

U. S. Engineer Office, New Orleans, La., August 1916

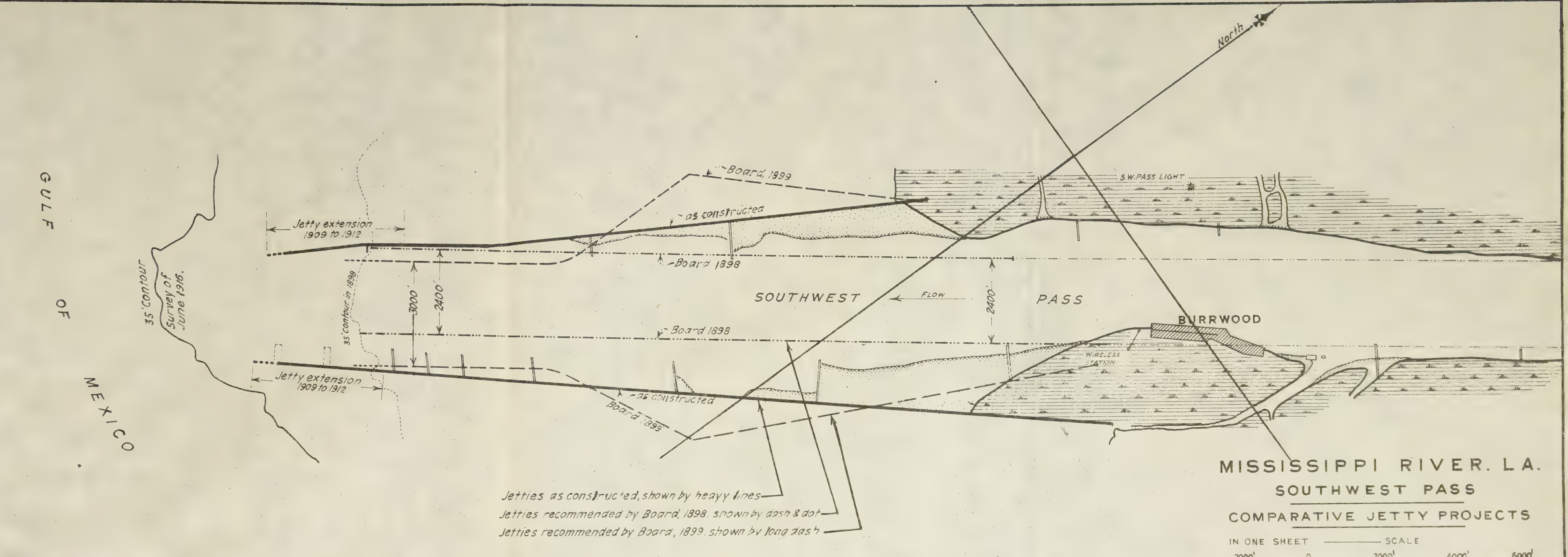
Submitted: J. L. Hortenstine, Assistant Eng'r.

Approved: Edward H. Schulz, Major, Corps of Eng'rs.

Drawn by: [illegible]. File Nº S.W.P. 12/50

emoir on Passes of the
dated Aug. 1, 1916.
H. Schulz, Corps of Eng'rs.

PLATE 2.



Name of Jetty	Plan of Board 1898	Plan of Board 1899	Modified plan of Bd. 1899	Constr. above water not including extension	Present Length above water
Project Length in feet EAST JETTY	21,000'	20,600'	23,000'	21,000'	23,900'
" " " " WEST JETTY	18,300'	16,000'	17,000'	15,000'	18,400'

To accompany memoir on Passes of the Mississippi River, dated Aug. 1, 1916.
By Major Edward H. Schulz, Corps of Eng'rs.

MISSISSIPPI RIVER. LA.

SOUTHWEST PASS

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Drawn by: ... File No S.W.P. 12/50

PLATE 2

Average areas below datum on same cross-section.

	South Pass Square feet.	Southwest Pass Square feet.	Pass a Loutre Square feet.
1898	16,595	74,719	82,529
1905	17,884	75,791	72,367
1909	21,424	76,300	77,258
1914	24,197	73,555	79,521
1915	23,479	72,047	78,420

Average per cent of total discharge at Head of Passes.

	South Pass Per cent.	Southwest Pass Per cent.	Pass a Loutre Per cent.
1898	8.6	41.4	50.0
1905	9.2	46.1	44.7
1909	11.2	43.9	44.9
1914	12.7	41.2	46.3
1915	14.1	40.9	45.0

9. *Discharge measurements.* Humphreys and Abbot in 1860 (pp. 146 and 148 of their report) concluded from their observations that the Mississippi's mean total annual discharge at Carrollton was 19,500 billion cubic feet, or including three outlets above (Old River, Plaquemine Bayou, and Bayou Lafourche), about 21,300 billion cubic feet, with about 443,000,000 tons of sediment. This brings the mean annual discharge to about 675,000 second-feet, and an annual deposit of sediment 1 mile square and 263 feet high, or including deposits on the delta, 290 feet high.

On page 475, Humphreys and Abbot give the mean discharge of low river as 300,000 second-feet during a period of from 2 to 7½ months, and the mean discharge of high river as 1,000,000 second-feet for an average period of 4 to 8 months. They considered high water anything over 800,000 second-feet, and stated that in 1855 the discharge did not exceed 700,000 second-feet.

Observations by the Mississippi River Commission in 1912 and 1913. During the greatest flood on the lower river—that of 1912—the Mississippi River Commission determined, May 15, at Red River Landing, with local standard gauge at 53.2 feet, a discharge of 1,305,606 second-feet, or including wastage over banks, 1,499,462 second-feet. Also, on May 11, 1912, with Carrollton gauge at 20.7 feet (highest record), the determined discharge was 1,309,818 second-feet, or, adding wastage, 1,312,242 second-feet. This agrees

for river proper very closely to Red River Landing discharge on May 15.

The Mississippi River Commission observations for February 10, 1913, with a stage of 15.6 feet at Carrollton, gave a discharge of 1,048,815 second-feet, or, including wastage, a total of 1,051,465 second-feet.

Discharge observations by New Orleans District in 1915. These observations covered a period from January 12 to November 5, when the Carrollton gauge was at and above 5 feet. The discharge determined during these observations showed a maximum and average of each pass as follows:

	Average. Cubic feet.	Maximum Cubic feet.
South Pass	81,633	124,997
Southwest Pass	236,808	353,241
Pass a Loutre	260,974	362,063

The observations showed that the average rate of discharge above The Jump, from January 12 to November 5, was 687,877 cubic feet, amounting to a total for that period (299 days) of 17,800 billion cubic feet. This amounts to about 91.3 per cent of the mean annual discharge found at Carrollton by Humphreys and Abbot.

The greatest discharge actually determined in 1915 by this office, on all the outlets at the same time, was:

	Second feet.
June 28. Three passes	732,312
June 29. The Jump	27,510
June 29. Cubits Gap	116,226
Total	876,048

This, however, was not the maximum for the year. The maximum at Head of Passes was on March 1, with the Fort Jackson gauge reading 6.7 feet and the Carrollton gauge 15.1 feet, and amounted to 834,037 second-feet. On July 13, the Fort Jackson gauge was at 6.7 feet and the Carrollton gauge at 12.7 feet, and the discharge on that date was 28,140 second-feet for The Jump and 116,846 second-feet for Cubits Gap. This would make a total discharge of 979,023 second-feet, or, allowing for wastage and a rise to correspond with the 15.1-foot stage at Carrollton on March

Observation.		Areas						
o.	Date, 191	W. S. Sq. Ft. Below	Below Datum Sq. Ft.	Scour=s Fill=f (Feet)	Mean Velocity. Ft. per sec.	Discharge Cu. ft. per sec.	Carrollton Gauge. (Feet.)	Wind.
1	March 31	33,325	79,607	----------	3.928	327,296	15.15	Light II.
2	March 31	33,785	80,067	s=460	3.967	332,383	15.15	Light II.
3	March 31	33,785	80,067	----------	3.889	325,814	15.15	Light II.
4	April 1	34,253	79,613	f=454	3.617	304,743	15.00	Light I.

TICAL SECTIONS.

auge=4.9′ R—Wind Light I.

of depths noted.

Statio	0.5	0.6	0.7	0.8	Bottom.
184	2.384	2.217	2.086	1.894	1.870
269	3.185	3.005	2.683	2.516	2.145
391	3.376	3.197	3.006	2.408	2.587
428	3.233	3.018	2.886	2.444	2.050
596	3.412	3.089	2.886	2.121	1.584
687	3.687	3.466	2.910	2.540	2.145
748	3.209	2.662	2.564	2.277	1.966
800	3.615	3.293	2.898	2.086	2.062
949	4.810	4.464	4.332	3.436	3.101
1045	5.037	4.655	4.392	4.296	3.806
1106	4.667	4.440	4.272	4.302	3.782
1201	4.045	3.950	3.591	3.448	3.352
1347	3.854	3.566	3.531	3.257	3.137
1498	2.862	2.743	2.755	2.396	2.444

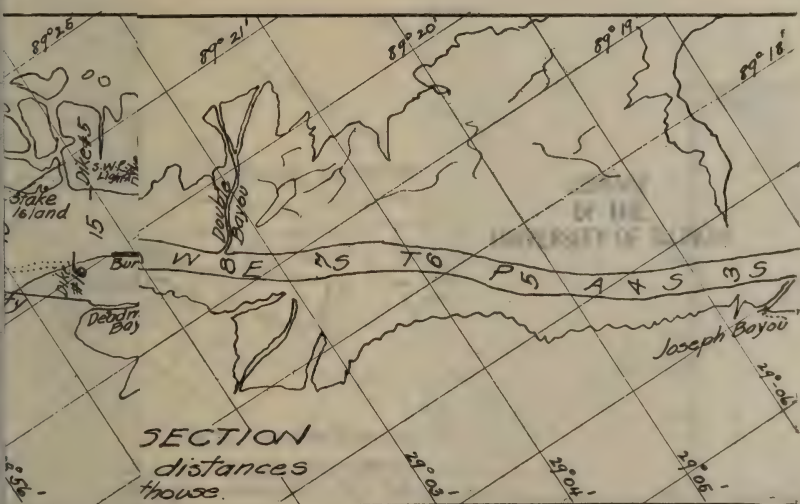
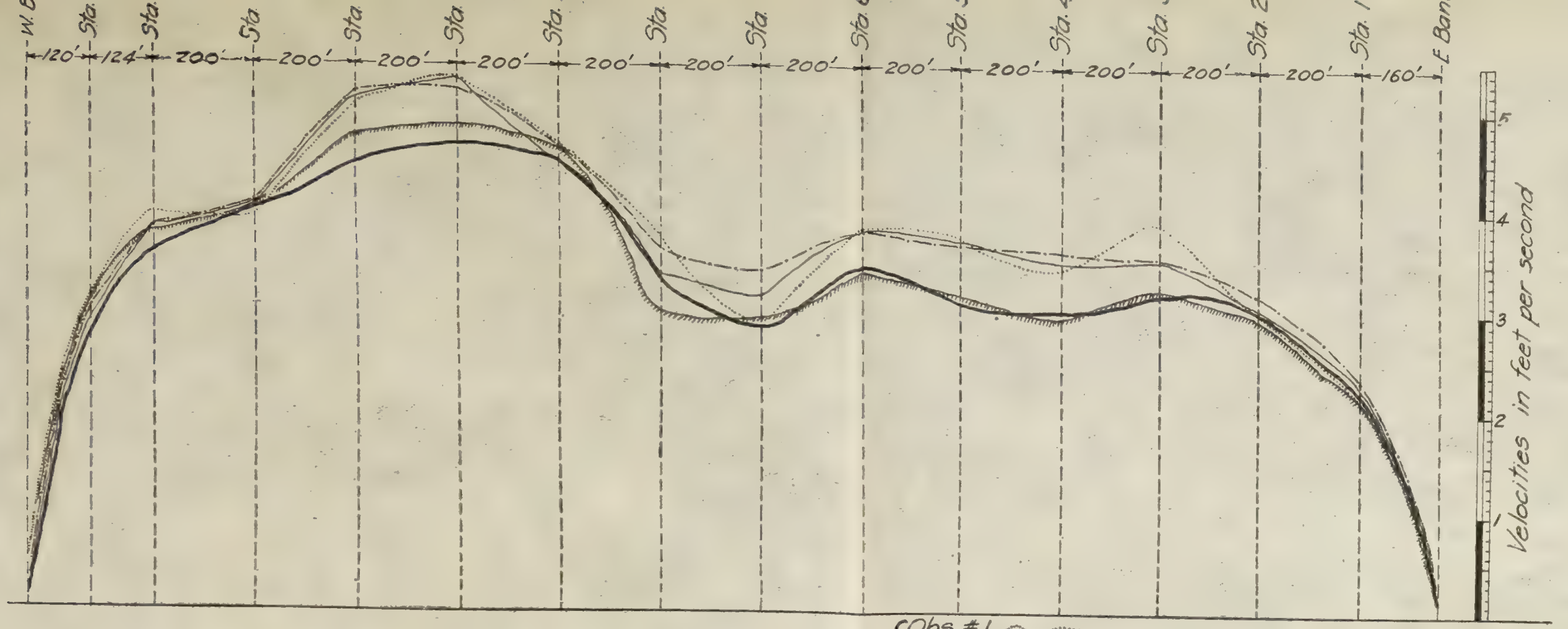


PLATE III.

SOUTHWEST PASS, MISSISSIPPI RIVER

DISCHARGE OPERATIONS



VELOCITIES AT $\frac{6}{10}$ of the DEPTH { Obs. #1, Obs. #2, Obs. #3, Obs. #4, Obs. #5

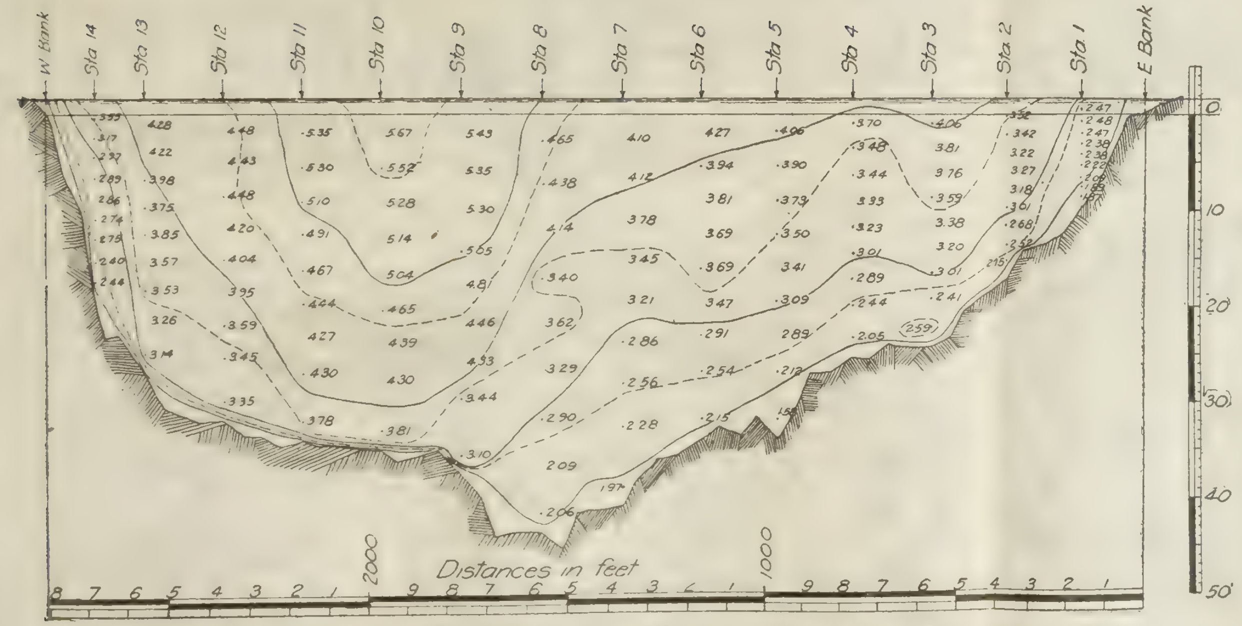
Observation. No.	Observation. Date, 1916.	Burrwood Gauge (Feet) R=Rising S=Stationary F=Falling	Mean Depth Below W. S. (Feet.)	Mean Depth Below Datum. (Feet.)	Maximum Depth. (Feet.)	Width. (Feet.)	Areas Below W. S. Sq. Ft.	Areas Below Datum Sq. Ft.	Scour=s Fill=f (Feet)	Mean Velocity. Ft. per sec.	Discharge Cu. ft. per sec.	Carrollton Gauge. (Feet.)	Wind.
1	March 31	4.3 R	29.13	27.83	46.9	2860	83,325	79,607	....	3.928	327,296	15.15	Light II.
2	March 31	4.3 S	29.30	28.00	47.3	2860	83,785	80,067	s=460	3.967	332,383	15.15	Light II.
3	March 31	4.3 F	29.30	28.00	47.3	2860	83,785	80,067	.. ..	3.889	325,814	15.15	Light II.
4	April 1	4.6 R	29.05	27.45	46.9	2900	84,253	79,613	f=454	3.617	304,743	15.00	Light I.

VELOCITIES IN VERTICAL SECTIONS.

Observation No. 5—Burrwood Gauge=4.9′ R—Wind Light I.

Velocities at fractions of depths noted.

Stations.	Depth below W.S.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	Bottom.
1	11.5	2.468	2.480	2.468	2.384	2.384	2.217	2.086	1.894	1.870
2	18.9	3.520	3.424	3.221	3.269	3.185	3.005	2.683	2.516	2.145
3	25.9	4.057	3.806	3.759	3.591	3.376	3.197	3.006	2.408	2.587
4	27.0	3.699	3.484	3.436	3.328	3.233	3.018	2.886	2.444	2.050
5	35.5	4.057	3.902	3.735	3.496	3.412	3.089	2.886	2.121	1.584
6	35.5	4.272	3.938	3.806	3.687	3.687	3.466	2.910	2.540	2.145
7	42.5	4.105	4.117	3.782	3.448	3.209	2.662	2.564	2.277	1.966
8	45.0	4.655	4.380	4.141	3.400	3.615	3.293	2.898	2.086	2.062
9	38.8	5.426	5.348	5.300	5.049	4.810	4.464	4.332	3.436	3.101
10	36.5	5.671	5.515	5.284	5.145	5.037	4.655	4.392	4.296	3.806
11	35.5	5.348	5.300	5.097	4.906	4.667	4.440	4.272	4.302	3.782
12	33.5	4.476	4.428	4.476	4.201	4.045	3.950	3.591	3.448	3.352
13	28.5	4.284	4.225	3.974	3.747	3.854	3.566	3.531	3.257	3.137
14	21.0	3.554	3.173	2.970	2.898	2.862	2.743	2.755	2.396	2.444



VELOCITIES IN CROSS-SECTION (Obs. No. 5). Figures denote velocities in feet per second.

Zero of vertical scale is at M. L. W.=3.42 feet on Burrwood gauge.

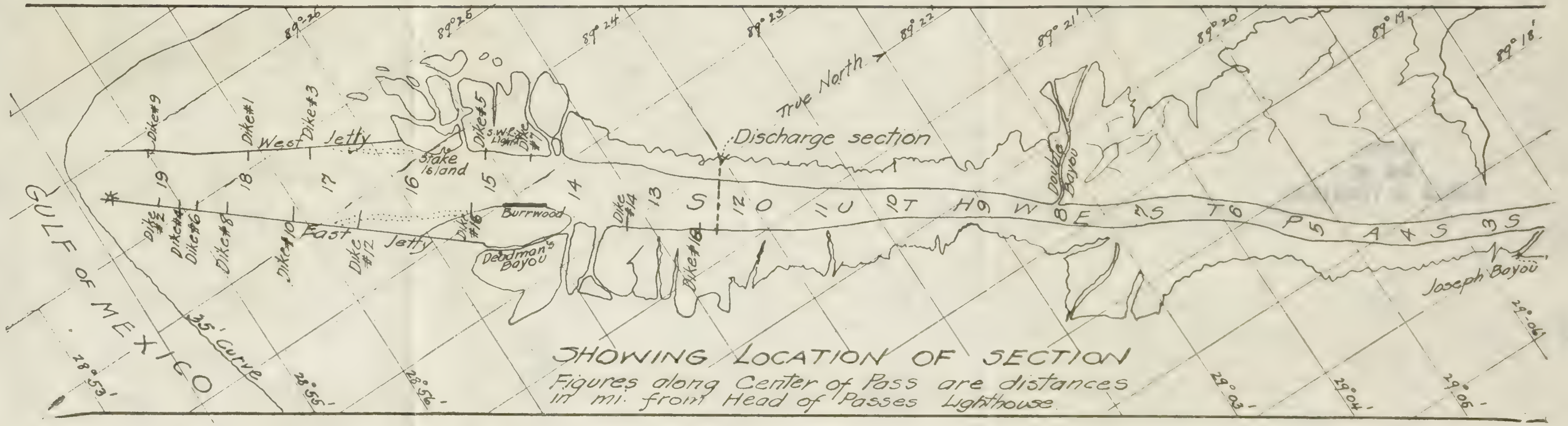


PLATE III.

SOUTHWEST PASS, MISSISSIPPI RIVER

DISCHARGE OPERATIONS

1, the total may be stated as 1,000,000 second-feet, or more, for the maximum of the year.

Discharge observations by New Orleans District in 1916. The accompanying map (Plate 3) shows the discharge section in Southwest Pass, observations at which were taken March 31 and April 1, 1916.

Date.		Carrollton gauge. Feet.	Mean velocity. Feet per second.	Discharge. Second-feet.
Mar. 31	Rising tide	15.00	3.928	327,296
	Stationary tide	----	3.967	332,383
	Falling tide	----	3.889	325,814
Apr. 1	Rising tide	15.00	3.617	304,743
	Mean discharge			322,559

Maximum velocity was 5.87 feet per second and minimum velocity 1.87 feet per second.

The section taken was 2 miles above Burrwood; the surface width was 2,800 feet, and the maximum depth 45 feet. The observations at the head of Southwest Pass during the high water of 1915, about March 1 to 15, with Carrollton gauge at 15.00 feet, gave a mean discharge for six observations of 332,504 cubic feet. This agrees very closely with the 1916 readings, the difference representing about the wastage over the marsh and through sloughs, between Head of Passes and Burrwood.

10. *Current velocities in the Passes.* Observations were made in April, 1916, to determine the velocity and direction of the current in the lower portion of South and Southwest Passes. During the time of observation, Carrollton gauge registered from 13 to 15 feet, and observations were made at rising and falling tide. The average velocity at mid-depth for the Jetty Channel at South Pass, a distance of 2½ miles from Port Eads to end of jetties, was 4.82 feet per second. The average surface current was 4.73 feet per second. The mean for a 30-foot depth, being as near the bed as possible, was 5.12 feet per second, in center of channel.

In Southwest Pass, the currents were determined for a distance of about 7 miles, extending from 2 miles above Burrwood to end of jetties. The mean surface velocity was 3.68 feet per second and the mean mid-depth velocity was 3.71 feet per second. The mean velocity

at a depth of 18 feet (as near bottom as practicable) was 3.68 feet.

The comparison shows that the velocities in South Pass are about 30 per cent greater, which accounts for the greater scour and better channel at this pass. The average central and side depths of South Pass Jetty channel are 43 feet, and of Southwest Pass about 35 feet in the channel and about 20 feet on each side of the channel.

The general direction of the current in Southwest Pass is parallel to the axis of the pass when not influenced by the wind; the filaments spread out or move closer together as the width between banks and jetties increases or diminishes, and in consequence the current varies both in rate and direction. The direction of the current in South Pass is generally parallel to the channel axis and to the jetties.

11. *Gulf currents at mouths of Passes, previous knowledge.* Information on these currents has been based principally on statements of mariners giving their impression that the currents were towards the west.

Humphreys and Abbot, in their report of observations made in 1851 to 1860, state on page 499 as follows:

> The observations taken for a littoral current were such as to induce the belief that none exists, at least within the range of our experiments. An inspection of the courses of the passes may lead to the same conclusion, for their degree of divergence appears to be equal in all directions, which would not be the case if there were a current to carry the earthy matter, which forms their banks, to the one side or the other.
>
> Temporary causes may produce a current for the time, running in the one or the other direction, according to the influencing cause. Thus, when the wind has been blowing for a long time in one direction, it banks up the water of the Gulf, bays and streams that lie in that direction; this produces a return current when the wind lulls. The southerly winds, I believe, prevail, though at the time we were there they were mostly from the north and east.

On page 507, they state:

> The prevailing winds being from the east, and the axis of the pass southwest, the general set of the current is to the west; hence may have arisen the idea of a "westerly littoral current." Care was taken to make the observations under all circumstances of wind and tide, and no traces of the existence of such a current is shown within 7 miles of the land—the extreme point to which the observations were carried.
>
> There are no regular currents in the bays, but such as depend on the wind and tides.

Again, on page 477 they report:

After a very elaborate examination of the observations, the following conclusions have been reached:

During the period of flood, the water in contact with the bar, as far as the outer crest, is fresh, and moves seaward with a comparatively rapid current. Beyond the outer crest and below the stratum of fresh water, salt water is found in contact with the outer slope of the bar, moving seaward with a velocity varying between 0.3 and 2.5 feet per second, the mean being about 0.5 of a foot per second. The direction of this motion, however, is not parallel to that of the river water, the angle between them being often as great as 20 degrees. On one occasion, during a strong southerly wind, a little salt water began to make its appearance below the fresh on the inner slope of the bar.

During the low-water period, the water in contact with the bar is always salt; moving sometimes outward and sometimes inward—but always with a gentle current—and sometimes remaining at rest. At the outer crest of the bar, when the tides are greatest and rising, there is an inward current of salt water at the bottom, increasing in strength with the rise in the tide. When the tide turns, the current changes its direction and moves outward. In this stage of the river, the surface water is usually brackish to the Head of the Passes, and sometimes as far up as Fort St. Philip. During extraordinary gales, the Gulf water has been known to fill the channels of the passes with an upstream current.

Report of E. L. Corthell. In "History of the Jetties at the Mouth of the Mississippi River," by E. L. Corthell (page 15), it is stated:

The tidal wave approaches the mouth of the Mississippi from a southeasterly direction, and creates a current past the delta which varies from 0.3 of a foot to 2.5 feet per second, the mean being about 0.5 of a foot.

The winds exert an important influence; they have the characteristic of the northeast trade winds.

Again, on pages 232 and 233, in the same history, it is stated:

The existence of a littoral or shore current at the mouth of South Pass, which has been most emphatically denied by the opponents of the jetties, is clearly proven by the following facts.

In February, 1875, Prof. Henry Mitchell, of the United States Coast Survey, made observations to decide this question. At the date of these observations the weather was calm with a slight breeze from the north. He established one section across the pass at the lighthouse, and another about 2,200 feet in length in 20 feet of water, immediately beyond the crest of the bar, and parallel with the face of it. Careful gauging of the volume passing through these sections gave 23,547 cubic feet per second at the lighthouse and 107,596 cubic feet per second at the section outside the bar. This was more than four times as much as the former, although a considerable portion of the volume had escaped laterally over the outlying reefs before reaching the crest of the bar.

The average velocity, from surface to bottom, was 30 per cent greater than that at the lighthouse, and the maximum velocity of the 6-foot depth was

100 per cent greater. A deflection of the current to the westward was noticed. These observations proved the existence at that time of either a littoral current or a race of the sea.

On May 27, 1874, Mr. Bayley published a letter in the New Orleans *Picayune*, in which he gave some facts relative to a littoral current. He referred to the captains of steamships and to the experience of fishermen, to prove that there is a regular coastwise westerly current, except only when temporarily checked by westerly or southwesterly gales, and that steamers make better runs westward than eastward. He referred to the Coast Survey report of 1853, to show that important changes at the Grand Pass entrance to Barataria Bay were caused by the strong westerly currents of the Gulf. He says further modern current charts correctly represent the great equatorial current as sweeping in its resistless course around the Gulf of Mexico, across and near the mouths of the passes, and that an eddy current commences there and flows westward along the Louisiana coast.

Observations and experience during the construction of the jetties show that the shore current which exists there is not always westward, but under the influence of westerly winds, has sometimes been found to be quite strong to the eastward.

On March 13, 1878, Captain Brown found a current of 3 feet per second at the bottom, moving to the eastward. The location of his observation was 600 feet beyond the end of the jetties, in 28-foot depth of water. The surface current of fresh water was moving straight out. But the prevalence of the current to the west, which is doubtless due principally to the prevailing winds, is shown by the fact that drift logs of the Mississippi River, drift lumber from the jetties, and the buoys along the delta that break from their fastenings, are found invariably along the coast of western Louisiana and Texas.

12. *Surface currents at Gulf entrance, Southwest Pass, 1915-16.* Observations were made by the New Orleans office at the mouths of South and Southwest Passes during the spring of 1916, and also to some extent at Southwest Pass during 1915.

The direction of the surface current is governed largely by the wind. The river water on issuing into the Gulf rises upon the denser sea water and spreads over the same.

In April and May, 1915, observations of surface currents directly in jetty channel and prolongation gave velocities of 5 to 6.1 feet per second just beyond jetty and before reaching bar; over the bar the velocities ranged from 4.5 to 5 feet, and beyond the bar at about 1 mile the currents were 4 to 5 feet. The general directions were a little to the west of the jetty axis. The stage was 7.8 feet on the Carrollton gauge. Some observations for subsurface were also taken.

The general velocities in April, 1916, were as follows: At the

crest of the bar, about 4.5 feet per second, gradually diminishing at a distance of 4 to 5 miles to $2\frac{1}{2}$ feet per second. The velocities along the paths of the floats directly in front of jetty entrance ranged from 2 feet at a distance of 5 miles from the bar to 4.95 feet immediately in front of the bar. The velocities on the sea side of the jetties, close in to the ends, were about 0.5 foot per second, increasing to 1.5 to 3.0 feet as they moved seaward into the main body of the river water. Those floats to the left of the jetty entrance went to the southeast and southwest, the falling tide producing a current more to the west. Those floats to the right of the jetty entrance moved to the west and southwest. The stage of river was 13 to 14 feet on Carrollton gauge.

13. *Surface currents at entrance, South Pass, 1916.* The movement of the surface water after passing the jetty entrance at South Pass was determined by floats run over a course of about 2 miles. The velocity directly in front of the entrance ranged from 1.06 to 3.86 feet per second, the mean being 2.96 feet per second. The direction was generally in prolongation of the jetty axis, moving approximately parallel to the subsurface currents.

The floats to the eastward of the entrance gave a velocity ranging from 0.29 to 0.92 foot per second, the mean being 0.61 foot per second. The direction of the current was erratic, running to the southeast and around to the northwest; the general direction, however, was to east and northeast. The floats to the westward of the entrance gave a velocity ranging from 0.31 to 2.06 feet per second, the mean being 1.30 feet per second. The direction ranged from southeast to southwest, the prevailing direction being toward south.

14. *Subsurface currents at entrance Southwest Pass, 1915-16.* During April, 1915, some observations were taken directly in front of the bar at the jetty entrance for about the first mile and one-half. The subsurface velocities (depths 30 to 40 feet) were found to run from 2.2 to 3.3 feet per second, with an average of 3 feet. The direction was not parallel to the river water, there being an angle to the westward as great as 20 degrees between the river current and the subsurface current. The depth of river water flowing over the salt water was about 15 feet. The river flow, however, had an influence on the subsurface current to a somewhat greater depth. The prevailing winds were easterly to southeasterly for most of the ob-

servations. In one case the winds for the previous week were westerly, which tended to force the current more to the eastward.

The direction and rate of the subsurface current at the Gulf entrance to Southwest Pass were determined for every 10 feet, down to the 90-foot depth. The direction and velocity of the currents were determined by floats run over a course ranging about 3½ miles in length. The average rate of the current over the entire course ranged from 0.57 foot to 1.94 feet per second, and the currents moved to south and east for those floats to the east of the entrance, and to south and southwest for those to the west of the entrance. For falling tide, the currents were slightly more to the westward. The velocities along the course of the floats ranged as high as 2.95 feet per second, and the average velocities ranged from 1.2 to 1.6 feet per second. The floats at different depths below the influence of the river water moved along lines approximately parallel. The variation in direction was on different days, the direction being fairly constant throughout any one day. The change in direction took place slowly, covering several days, and the change was probably due to change of the wind and tide and movement of the Gulf stream off the mouth of the river.

The movement of the upper 9 and 20 foot strata of water in front of the Southwest Pass jetties was determined on July 31 and August 1, 1916, by allowing the dredge *New Orleans* and the tug *C. Donovan* to drift with the current over a course of about 12 miles in length, beginning near the crest of the bar on the east and west sides of the jetty entrance. The velocity of the 9-foot stratum was about 100 per cent greater on the west side and 30 per cent greater on the east side than the 20-foot stratum. The general direction ranged from about west by south at the jetty entrance to west 12 miles from the jetties. The average velocity of the 20-foot stratum over the entire course was 2.39 feet per second, and for the 9-foot stratum 3.99 feet per second. The velocities along the course of the dredge varied from 2.02 to 3.7 feet per second; the velocities along the course of the tug varied from 2.56 to 4.93 feet per second. The direction of the current was more to the westward during falling tide. The wind, during the time of observation, varied from northeast to east. Carrollton gauge read 8.5 during the observation.

The greater velocity of the light-draft vessel is probably due to the greater influence of the river discharge on the surface currents.

15. *Subsurface currents at entrance South Pass, 1916.* Observations were made in the Gulf in front of and on each side of the South Pass jetties to determine the movement of the Gulf water. In front of the jetties the velocity ranged from 1.85 to 4.17 feet per second, the average being 3.05 feet per second; the direction of the current was approximately parallel with the jetty axis, spreading both to the south and southeast seaward of the jetty entrance.

Floats at the east of the entrance were very erratic, due to eddies, and ran generally from east to north; velocities, 0.13 to 0.47 foot per second, the mean being 0.33 foot per second.

The floats at the west of the entrance moved in a direction southeast to south; the velocities ranged from 1.41 to 2.62 feet per second, the mean being 2.02 feet per second. These velocities are greater than those to the east of the jetties, as the floats were in a greater proximity to the jetty axis.

Observations with rod floats were made at mouth of South Pass on August 2 and 10, to determine the upper 8 and 15 foot strata. The floats on the west side moved about south for the first mile and then moved southwest to west; the velocity of the 8-foot float was about 0.50 foot per second at the beginning, increasing to 3.33 feet; the velocity of the 15-foot float was 0.63 foot at the beginning, increasing to 2.50 feet. The floats on the east side moved south for first mile and then turned southeast; the velocity of the 8-foot float at the beginning was 2.2 feet per second and decreased to 1.1 feet; the velocity of the 15-foot float ranged from 1.4 to 2.3 feet per second. The observations of August 2 and 10 showed wide divergence.

16. *Comparison of outer currents at South and Southwest Passes.* The subsurface currents outside of Southwest Pass, and not in direct line of the jetties, were found greater than at South Pass; but those in line of the jetties were found greater at South Pass, due to the greater concentration and velocity of the river water at South Pass.

The surface currents in the Gulf at Southwest Pass were generally greater than at South Pass, on account of the more rapid lateral spread and the greater volume of river discharge at Southwest Pass.

In general, the movement of the surface water predominates somewhat to the westward, due primarily to the prevailing easterly

winds; this conclusion is also borne out by the fact that the larger portion of the river-borne sediment is deposited to the westward of the Passes. The prevailing direction of the subsurface currents tended to the eastward, or more easterly than the surface currents, due possibly to the influence of the main Gulf Stream. The direction of these currents is, of course, being continually modified by the conditions of the wind, tide, and storms.

17. *Prevailing winds.* As already stated, the prevailing wind ranges from northeast to southeast, being northerly during the season of cold weather and southerly during warm weather. During the winter months frequent northwest winds occur, having a velocity from 30 to 50 miles per hour; and at the time of autumnal equinox, storms visit the mouth of the river, having a sustained wind velocity ranging from 60 to 90 miles per hour. During the hurricane of September 29, 1915, there was a sustained wind velocity of over 78 miles per hour for a continuous period of eleven hours, a maximum velocity of 140 miles per hour being reached during the interval. A wind chart for fiscal year 1916 is shown on Plate 1.

18. *Tides.* Automatic tide gauges are in use at the mouth of South and Southwest Passes, and at the Head of the Passes. The tides are diurnal, there being one high and one low tide each day. The tidal wave approaches from the southeast. The mean range of tide is approximately 16 inches at the mouth of the river. Variations of water level due to wind vary from a few inches to as much as 3 feet. During tropical storms, the water surface rises 5 to 6 feet above mean low tide.

The storm of September 29, 1915, raised the water level at South Pass to 3.74 feet above mean Gulf level, and at Southwest Pass, on the same day, the water rose to 5.76 feet above mean Gulf level, the maximum on record.

19. *Specific gravity and salinity of waters at and near mouths of Passes.* For Humphreys and Abbot's discussion of movement of salt and fresh water, see paragraph 11 above.

The following additional information is taken from the Report upon the Physics and Hydraulics of the Mississippi, by Humphreys and Abbot, page 498:

The specific gravity of the fluid, within and without the bar, was also found by a series of experiments. Those within the bar gave, as an average, 1.00033, distilled water being 1.00000. Without the bar no experiments could

Mean low water
1.0080
1.0175
1.0185
9
8
3
2
1
0 Ft. =
1.0069
1.0145
1.0207
1.0242
50 Ft.

PLATE 13

TABULATED RESULTS OF ANALYSIS OF WATER BEYOND CREST OF BAR

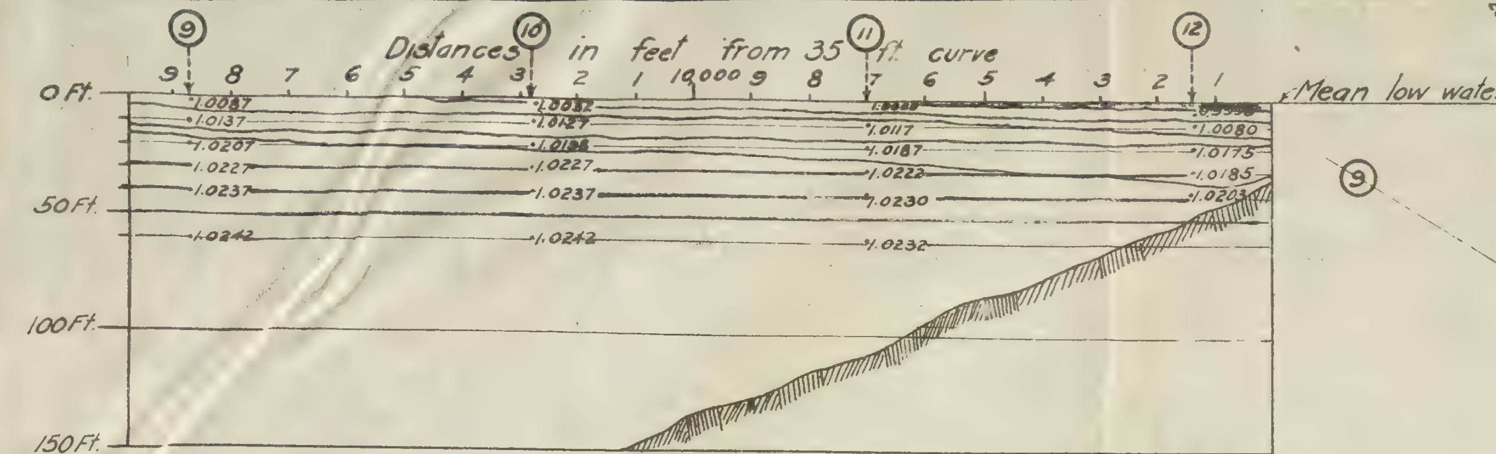
LOCATION NO.	SAMPLE NO.	DEPTH BELOW SURFACE FT.	TEMP. °FAHR.	SPECIFIC GRAVITY *	COLOR	SEDIMENT	TASTE	BURRWOOD GAUGE (FT.)	TIDE R = RISING S = STNERY F = FALLING	WIND FORCE and DIRECTION
1	1	0	65	1.0103	MK.	S.A	S'ty.	4.45	R	NE. - 5 MI.
1	2	10	69	1.0168	S.MK.	T.	V. S'ty.	"	R	"
1	3	15	69	1.0178	S.MK.	T.	V. S'ty.	"	R	"
1	4	30	70	1.0228	V.S. MK.	S.T.	V. S'ty.	"	R	"
1	5	40	70	1.0235	C.	S.T.	V S'ty.	"	R	"
1	6	60	69.5	1.0247	C.	V.S.T.	V. S'ty.	"	R	"
2	1	0	62	1.0040	MK.	S. A.	T.	4.59	R	E.N.E. - 7 MI.
2	2	10	66.5	1.0142	MK.	S. A.	S'ty.	"	R	"
2	3	20	68	1.0212	S.MK.	T	V. S'ty.	"	R	"
2	4	30	68.5	1.0232	C.	S.T.	V. S'ty.	"	R	"
2	5	40	68.5	1.0232	C.	S.T.	V. S'ty.	"	R	"
2	6	60	68.5	1.0240	C.	V.S.T.	V. S'ty	"	R	"
3	1	0	64.5	1.0032	S.M.	S.A.	V.S.T.	4.72	R	E - 8 MI.
3	2	10	70	1.0137	MK.	T.	S'ty.	"	R	"
3	3	20	69.5	1.0217	S.MK.	T.	V. S'ty.	"	R	"
3	4	30	69	1.0222	V.S.MK.	T.	V. S'ty.	"	R	"
3	5	40	68.5	1.0237	C.	T.	V. S'ty.	"	R	"
3	6	60	68.5	1.0240	C.	S.T.	V. S'ty	"	R	"
4	1	0	64.5	1.0027	S.M.	S.A.	V.S.T.	4.77	R	E. - 7 MI.
4	2	10	72	1.0112	S.MK	T.	S'ty.	"	R	"
4	3	20	70	1.0162	V.S.MK.	T.	V. S'ty.	"	R	"
4	4	30	68	1.0237	V.S.MK.	T.	V. S'ty.	"	R	"
4	5	40	68	1.0237	C.	S.T.	V. S'ty	"	R	"
5	1	0	64	1.0067	MK.	S.A.	T.	4.80	R	E - 6 MI.
5	2	10	70.5	1.0192	——	——	——	"	R	"
5	3	20	70.5	1.0222	S.MK.	T.	S'ty	"	R	"
5	4	30	69.5	1.0237	S.MK.	T.	V. S'ty.	"	R	"
5	5	40	69	1.0248	S.MK.	T.	V. S'ty.	"	R	"
5	6	60	70	1.0250	C	S.T.	V. S'ty.	"	R	"
6	1	0	65.5	1.0037	S.M.	S.A.	V.S.T.	4.84	R	E. - 6 MI.
6	2	10	69.0	1.0157	S.MK.	T.	S'ty.	"	R	"
6	3	20	70.5	1.0218	S.MK.	T.	S'ty.	"	R	"
6	4	30	70	1.0225	S.MK.	T.	V. S'ty.	"	R	"
6	5	40	69	1.0420	S.MK.	T.	V. S'ty.	"	R	"
6	6	60	69	1.0257	V.S.MK.	S.T.	V. S'ty.	"	R	"
7	1	0	62.5	1.0002	M	S.A.	F.	4.87	R	E. - 5 MI.
7	2	10	72	1.0132	MK.	T.	S'ty.	"	R	"
7	3	20	70	1.0192	MK.	T.	S'ty.	"	R	"
7	4	30	70.5	1.0208	S.MK.	T.	S'ty.	"	R	"
7	5	40	69	1.0237	S.MK.	T.	S'ty.	"	R	"
7	6	60	69	1.0240	V.S.MK.	T.	V. S'ty.	"	R	"
8	1	0	61	0.9975	V.M.	N.	F.	4.91	R	E. - 4 MI.
8	2	10	65	1.0060	M.	S.A.	T.	"	R	"
8	3	20	68	1.0145	MK.	S.A.	S'ty.	"	R	"
8	4	30	68.5	1.0207	S.MK.	T.	S'ty.	"	R	"
8	5	40	68	1.0242	V.S.MK.	S.T.	V. S'ty.	"	R	"
9	1	0	67	1.0087	MK.	S.A.	S.T.	4.94	S	E. - 4 MI.
9	2	10	70	1.0137	S.MK.	T.	S'ty.	"	S	"
9	3	20	70.5	1.0207	S.MK.	T.	S'ty.	"	S	"
9	4	30	69.5	1.0227	V.S.MK.	T.	V. S'ty.	"	S	"
9	5	40	69	1.0237	V.S.MK.	T.	V. S'ty.	"	S	"
9	6	60	68	1.0247	C.	S.T.	V. S'ty.	"	S	"
10	1	0	63	1.0032	M.	S.A.	F.	4.95	S	E - 4 MI.
10	2	10	70.5	1.0127	S.MK.	T.	T.	"	S	
10	3	20	70	1.0198	S.MK.	T.	S'ty.	"	S	
10	4	30	70	1.0227	S.MK.	T.	S'ty.	"	S	"
10	5	40	69	1.0237	S.MK.	T.	V. S'ty.	"	S	"
10	6	60	68	1.0242	C.	S.T.	V. S'ty.	"	S	"
11	1	0	61.5	1.0005	M.	S.A.	F.	4.94	S	E. - 4 MI.
11	2	10	68.5	1.0117	MK.	S.A.	S.T.	"	S	"
11	3	20	70	1.0187	S.MK.	T.	S'ty.	"	S	"
11	4	30	70	1.0222	S.MK.	T.	S'ty.	"	S	"
11	5	40	69	1.0230	S.MK.	T.	S'ty.	"	S	
11	6	60	68	1.0232	C	T.	V. S'ty.	"	S	
12	1	0	61	0.9995	V.M.	N.	F.	4.93	S	E - 4 MI
12	2	10	66.5	1.0080	M.	S.A.	S.T.	"	S	"
12	3	20	69.5	1.0175	S.MK.	T.	S'ty	"	S	"
12	4	30	70	1.0185	S.MK.	T.	S'ty.	"	S	"
12	5	40	70	1.0203	S.MK.	T.	V. S'ty.	"	S	"

For Color —
- V.M. = VERY MUDDY.
- M. = MUDDY.
- S.M. = SLIGHTLY MUDDY
- MK. = MILKY.
- S.MK. = SLIGHTLY MILKY.
- V.S.MK. = VERY SLIGHTLY MILKY.
- C. = COLORLESS.

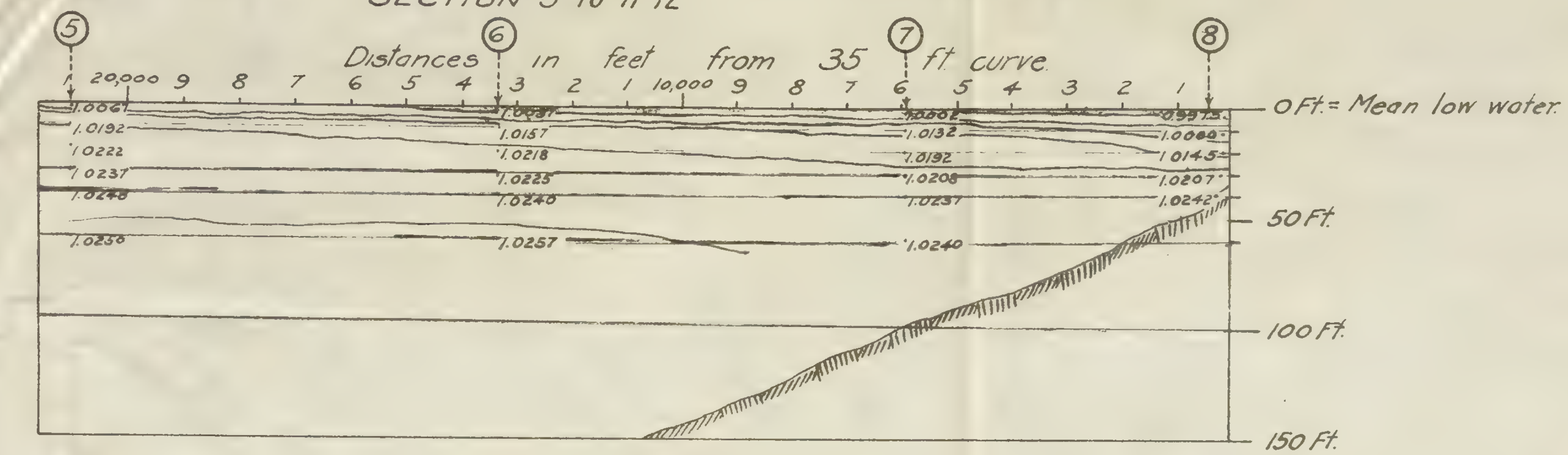
For Sediment
- N. = NORMAL AMOUNT (SAME AS IN RIVER FURTHER UP)
- S.A = SMALL AMOUNT.
- T. = TRACE.
- S.T. = SLIGHT TRACE
- V.S.T. = VERY SLIGHT TRACE.

For Taste —
- V. Sty. = VERY SALTY (PRACTICALLY PURE SEA WATER.)
- Sty. = SALTY.
- T. = TRACE OF SALT.
- S.T. = SLIGHT TRACE OF SALT.
- V.S.T. = VERY SLIGHT TRACE OF SALT.
- F. = FRESH.

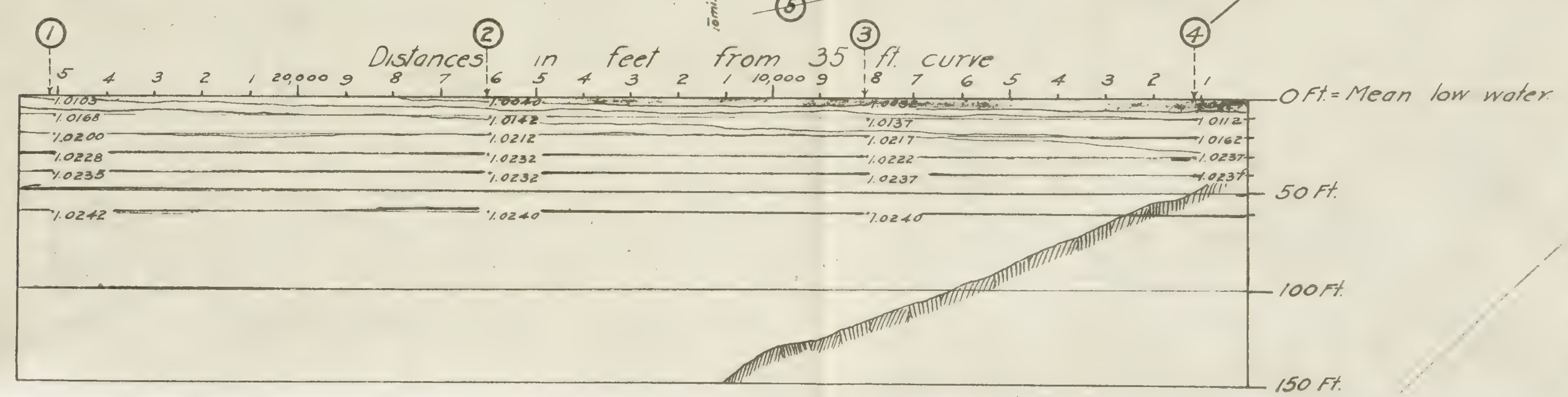
* Specific gravities given in table are the corrected means of the readings of a salinometer & Hydrometer calibrated to read 1.000 in distilled water at 60° F.



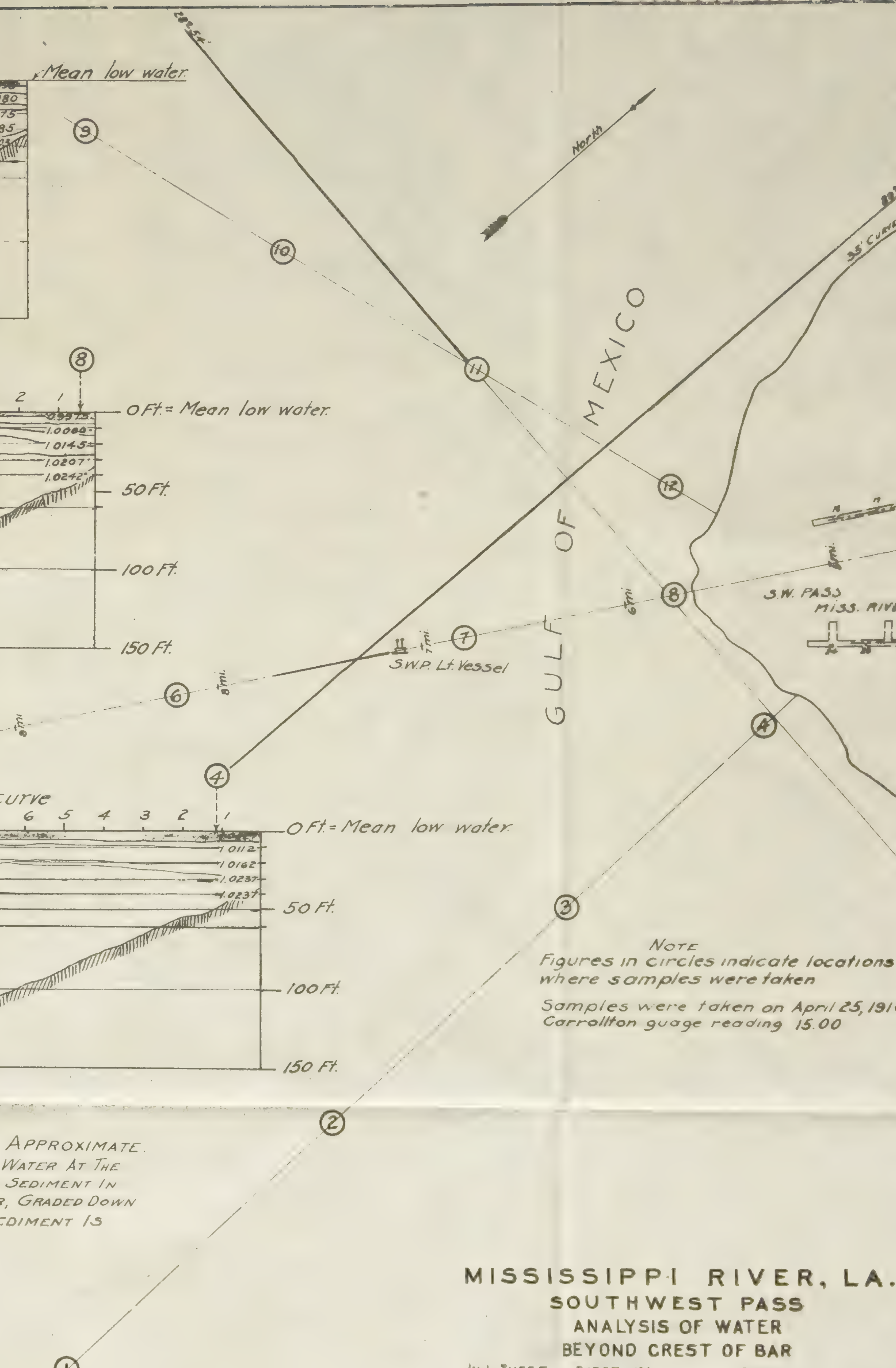
SECTION 9-10-11-12



SECTION 5-6-7-8



SECTION 1-2-3-4



NOTE

Figures in circles indicate locations where samples were taken

Samples were taken on April 25, 1916. Carrollton guage reading 15.00

LINE OF GULF BOTTOM SHOWN IN SECTIONS IS ONLY APPROXIMATE. FIGURES IN THE SECTIONS REPRESENT THE SPECIFIC GRAVITY OF THE WATER AT THE POINTS SHOWN. SHADED AREAS INDICATE THE RELATIVE AMOUNT OF SEDIMENT IN THE WATER; VERY HEAVY SHADING FOR NORMAL RIVER AND MUDDY WATER, GRADED DOWN TO NO SHADING FOR PRACTICALLY NORMAL SEA WATER WHERE SEDIMENT IS BARELY PERCEPTIBLE.

To accompany memoir on Passes of the Mississippi River Dated August 4 1916 By Major Edward H. Schulz, Corps of Eng'rs.

MISSISSIPPI RIVER, LA.
SOUTHWEST PASS
ANALYSIS OF WATER BEYOND CREST OF BAR

IN 1 SHEET SHEET No 1 SCALE: 2000' 0 2000' 4000' 6000' 8000'

U S Engineer Office New Orleans, La, August 1916

Submitted: J. H. Hortenstine Asst. Engineer

Approved: Edward H. Schulz Major Corps of Engr's.

Drawn by: L.R.G. File No 5.W.P 23/38a

PLATE 13

give definite results, excepting those in the clear salt water of the Gulf, which was found to be 1.0245. The other experiments give a variety of results, depending on the state of the mixture. It is to be remarked that the state of the mixture is different at times, according to the then and previous state of the weather. For instance, when the river is high and the weather calm for several days in succession, the river water spreading itself on the surface of the gulf water, extends directly out to a great distance, without mingling with the salt water below. In rough weather, on the contrary, the agitation of the waves serves to mingle the waters, and when the river is low, the salt water has been known to extend beyond the point of divergence of the Passes.

Observations were made in May, 1915, and April, 1916, to determine the specific gravity of the water at different depths at and near the sea entrance to the jetties at Southwest Pass.

The specific gravity at the crest of the bar in May, 1915, was 1.001 for the river water, having a temperature of 72 degrees; 1.024 for the sea water, having a temperature of 73 degrees, and 1.0145 at 10 feet below the surface where the river and sea water began to intermingle.

The average specific gravity of the sea water in front of the bar as determined in April, 1916, was 1.024, and the temperature 69 degrees; the specific gravity of the river water was 1.0009, and the temperature 62 degrees. The specific gravity in each instance is referred to a reading of 1.000 for distilled water at 60 degrees; temperature is referred to the scale of Fahrenheit.

Salt water was found at the bottom of the river channel 1 mile inside of the bar in May, 1915, when Carrollton gauge read 10 feet. Salt water was found in the river channel ½ mile inside the crest of the bar during the high stage of river in 1916, when Carrollton gauge read 20 feet. As the river stage falls, the salt water moves farther upstream until, at extreme low river, it very occasionally reaches as far as New Orleans. The undercurrent of salt water up the Passes during low stage of river causes what is known locally as "counter currents." These counter currents complicate the flow of water through the Passes at times to such an extent that the navigation of tows and low-power vessels is made difficult.

The plane of division between the river and sea water during April, 1916, at mouth of Southwest Pass, was found to rise about 1 foot in 1,000 feet. (See Plate 13.)

20. *Sediment.* The larger portion of the river sediment is carried far to sea, but a small amount of it is deposited in deep water immediately in front of the Passes and forms a foundation upon which eventually the coarser bar-building material is deposited;

this latter material is not carried in suspension, but is pushed along the river bed. The suspended material is composed of very fine sand, silt and clay. The bar is, therefore, composed of a coarser sand (but still quite fine) and clay sediment at the surface underlaid with soft silt and clay, and the entire formation rests upon the original Gulf bottom which, according to some geologists, is an impervious clay. The annual weight of sediment discharged at the mouths of the Passes is over 440,000,000 tons.

The amount of sediment carried in suspension by the Mississippi River was determined by experiments made at South Pass during the period from 1879 to 1901. These experiments showed that the proportion between the total discharge and the volume of sediment carried in suspension was 1 to 0.0007. These experiments, being continuous, included the period of low water when practically no sediment was in suspension; consequently, the proportion in flood is somewhat greater than stated above.

The larger amount of sediment was found on a rising river, and the amount did not vary with the velocity of the current. At times, when the velocity was decreasing regularly, the amount of sediment increased. In January, 1888, the maximum amount of sediment was found, and the proportion, by weight, of the discharge to the sediment was 1 to 0.0039, and the velocity of the current was 3.7 feet per second. Two months later, in March, 1888, the velocity was 4.5 feet per second, and the proportion was only 1 to 0.0022. The velocity varies with the stage of river, whereas the sediment increases for a short time with the rise in the river, but begins decreasing from one to three months before the river reaches its highest stage.

The following is a description of the method for determining the proportion of sediment to the discharge:

On two days during each week, samples of water, one quart each, were taken from a section near Port Eads. Five are taken from the center of the Pass, at the surface, at 8, 10, and 24 feet below the surface, and near the bottom, and three are taken at each of two stations about 150 feet from each shore, at the surface, mid-depth, and near the bottom.

The velocity of the current is then determined by five floats, at half mean depth, passing over a base of 200 feet.

In due time these samples of water are filtered, and the ratio of sediment to water by weight in each is determined, and the mean result for each day is an ordinate for the sediment curve; the proportion of sand contained in the sediment is estimated on examination of the latter under a microscope.

The proportion of sand during high stage of river was approxi-

mately 60 per cent of the sediment, and during low river approximately 40 per cent.

The following extract is from report upon Physics and Hydraulics of the Mississippi River, by Humphreys and Abbot, concerning experiments carried on at Carrollton, in 1851, to determine the amount of sediment in suspension and its relation to the velocity of the current (pages 674 and 675):

These results prove that the greatest velocity does not correspond with the greatest quantity of earthy matter held in suspension. On the contrary, at the time of the greatest velocity of the current at Carrollton, the river held in suspension but little more sediment per cubic foot than when the velocity was least. When the quantity of earthy matter held in suspension was greatest, the velocity was 2 feet less than the greatest velocity; the quantity of earthy matter in one case being three times as great as in the other. We found at another time, when the velocity was one-half the greatest velocity, the quantity of earthy matter held in suspension was double in amount.

. . . .

The following table, illustrating what has just been said, has been prepared from the report on the Mississippi River. The figures given express the condition existing not only on the one day noted, but on several successive days.

During the whole period of observation, the river bed remained unchanged. It will be noticed that even the maximum amount of sediment in the river water is a very small quantity compared with the mass of water; it being by weight in the proportion of 1 ounce of fine earth to 680 ounces of water, and by volume 1 cubic inch of earthy matter to 1,360 cubic inches of water.

. . . .

1. *Carrollton, 1851.*

Date.	Weight, in grains, of sediment in 1 cubic foot of water.	Mean velocities of river, in feet per second.	Remarks.
February 20	450	5.5	
March 20	200	6.2	
April 15	150	5.6	
May (last week of)	100	3.75	
June 20	650	4.3	Change in velocity regularly decreasing, while matter suspended remains the same.
July 10 to 30	450	4.8	
August 1 to 20	450	4.8-3.5	
September 8	300	3.0	
October and November	100	1.75	
December	175	1.85	
January 20, 1852	400	2.75	

Observations made in 1851-1852 at Carrollton to determine the relative amount of sediment at the surface, mid-depth and bottom, gave as a result: 20 per cent more sediment at mid-depth and 23 per cent more at bottom than at the surface. (Page 134, Humphreys and Abbot's Report.)

21. *Deposits and characteristics.* The average annual deposit of sediment from 1909 to 1915, in front of Southwest Pass out to the 80-foot depth is about 2 feet, the larger portion being to the westward of the entrance. (See Plate 14.)

The annual deposit in front of South Pass jetties is about 36 per cent as great as at Southwest Pass. The average depth from 1880 to 1916 measured on radial lines, at a distance of 4,000 feet from South Pass jetties, is 0.74 foot per year. (See Plate 16.) The annual average at 6,000 feet from jetties was 0.60 foot, and at 8,000 feet was 0.83 foot.

The material dredged from the Passes and bars consists of fine sand, silt and clay, and a small amount of vegetable matter. The sand is in excess during high river and decreases during low river. During the fiscal year 1915, physical analysis was made of the material dredged at South and Southwest Passes by the U. S. dredges *Benyaurd* and *New Orleans*. The two dredges removed during that year 3,909,624 cubic yards of sediment. The analysis of this material was as follows: 62.16 per cent fine sand, 37.06 per cent silt and clay, and 0.78 per cent vegetable matter. The sand was so fine that practically all of the samples passed a No. 60 sieve. The sediment (including sand and all materials) weighed from 75 to 115 pounds per cubic foot.

Physical analyses were made of two samples of sand taken from the discharge of the dredge *New Orleans* in April, 1916, while dredging in the lower portion of Southwest Pass. The sample taken while dredging in the channel opposite Burrwood gave the following results: 72 per cent retained on No. 100 sieve, 4 per cent retained on No. 74 sieve, and 24 per cent passed through No. 100 sieve. The sample taken while dredging on the bar gave the following results: 30 per cent retained and 70 per cent passed through a No. 100 sieve.

From a physical and chemical analysis of samples of sediment collected from banks and soil at the mouth of the Mississippi River in 1912 and 1913 by the Geological Survey, and published in Professional Paper 85-B, the following proportions were found: Fine gravel (2 to 1 mm.), 0.005; coarse sand (1 to 0.5 mm.), 0.12; medium

PLATE 14

NOTE—
Figures indicate the difference in depths of water between June 1909 and June 1915. Shaded portions indicate fill, unshaded portions, scour.
Average yearly advance of 35 ft. curve within the limits of survey is 274 feet.
Average yearly advance of 35 ft. curve in front of Jetties is 369 feet.

To accompany memoir on Passes of the Mississippi River, dated August 1, 1916.
By Major Edward H. Schulz, Corps of Engrs.

MISSISSIPPI RIVER SOUTHWEST PASS
AMOUNT OF SEDIMENT DEPOSITED AT
JETTY ENTRANCE

IN 2 SHEETS SHEET NO. 2

U.S. ENGINEER OFFICE, N.O., LA. MCH. 1916

Submitted: J. H. Hostetter [signature] Assistant Engineer

Approved: Edward H. Schulz [signature] Major Corps of Engineers

Drawn by F.D.C. & A.W.L. File No. S.W.P. 11/108

PLATE 14

PLATE 16


NOTES.
Surveyed by Allen E. Washburn. Jr. Engr.
Assisted by O.O. Melancon. Jr. Engr. E.J. Morano & A.H. Douglas. Insp.
Depths are expressed in feet. Contours in fathoms.
Reference plane = mean low tide = 3.3 ft. on East Bay gage.
Stage of river 15.5 to 14.4 feet on Carrollton gage.
Soundings taken on May 5, 9 & 12, 1916.
6; 12; 18; 24; 27; 30; 36; 42; 48; 54; 60; 66; 72; 78; 84; 90; 96; 102; 108; 114; 120; 126; 132; 138; 144; 150; 156; 162;
SOUTH PASS
JETTY
EAST JETTY LIGHT
EAST LUMP
Possible jetty extensions
CHAIN OF MUD LUMPS
1 MILE FROM E.J. LIGHT.
2 MILES FROM E.J. LIGHT.
3 MILES FROM E.J. LIGHT
3 Miles from E. Jetty Light
5 Fathom Curve
10 Fathom Curve
15 Fathom Curve
20 Fathom Curve
30 Fathom Curve
SEA BUOY
WRECK BUOY
BELL BUOY
ENTRANCE RANGE
OLD CHANNEL RANGE
GULF OF MEXICO.
To accompany memoir on Passes of the Mississippi River, dated Aug. 1916 by Major Edward H. Schulz, Corps of Engrs. U.S.A.
MISSISSIPPI RIVER.
SOUTH PASS.
GULF OF MEXICO FROM ENDS OF JETTIES TO DEEP WATER.
In 1 sheet Sheet No 1. Scale
1000' 0 1000' 2000' 3000'
U.S. Engineer Office N.O. La. May 1916. Port Eads, La., May 15, 1916
Prepared by: Allen E. Washburn Jr. Engr.
Submitted by: Cornelius Donovan Asst. Eng.
Approved: Edward H. Schulz Major, Corps of Engrs. U.S.A.
Drawn by E.J.M.
File No. 30 P. 17/29

PLATE 16

sand (0.5 to 0.25 mm.), 0.14; fine sand (0.25 to 0.1 mm.), 2.17; very fine sand (0.1 to 0.05 mm.), 23.38; silt (0.05 to 0.005), 52.65; clay (0.005 mm. or less), 21.39.

This paper also states:

Fine sand makes up about one-fifteenth of the material, and very fine sand a little over one-fourth. The great bulk of the material is silt, over one-half of all the particles measuring between 0.05 and 0.005 millimeter, or about 0.002 to 0.0002 inch. Even clay is present in the subordinate amount of 13 per cent, or a little more than one-eighth.

The chemical character of the material lying near the surface in the vicinity of the mouths of the river shows: SiO_2, 69.9; Al_2O_3, 10.6; Fe_2O_3, FeO and FeS, 3.4 per cent; and 15.7 per cent of miscellaneous matter consisting of the following: MgO, CaO, Na_2O, K_2O, H_2O, and a few other compounds.

It appears that the most rigid material in the delta is a mixture of sand and clay in certain definite proportions. Crusty layers "as hard as asphalt" are sometimes reported, and it seems probable that such layers do not consist of iron oxide or other uncommon material, but of a sand-clay mixture, and that there is every stage of gradation between this unusually resistent material and the very fluid clays. Experiments are now being made with mixtures of sand and clay, which it is hoped will furnish further information on this subject.

22. *Mud lumps.* The deposit of the heavy sediment on the soft silt and clay strata results in a displacement of the soft strata, which is forced up in front of the bar in the form of "mud lumps." These lumps complicate channel improvement and frequently accelerate the bar advance by causing a rapid deposit of sediment in the zone of slack water between the lumps and the crest of the bar. A reduction in the amount of sediment deposited on and near the bar will reduce the mud-lump formation. An extensive report on this matter from information partly furnished by the Engineer Department was made by the Geological Survey and published in Professional Paper 85-B.

23. *Advance of bars.* The advance of the Southwest Pass bar has varied from year to year, depending upon the stage of river and the work of improvement. The average annual advance between 1867 and 1915 was approximately 288 feet. The average annual advance during the past four years is approximately 290 feet. The advance of 70 and 80 foot curves has been about two-thirds as great as the 30 and 40 foot curves, and the western portion of the curve has advanced more rapidly than the eastern portion.

The average annual advance of the South Pass bar has been about 53 feet per year; the advance has been irregular and the

crest of the bar is not very well defined. The greater depth curves at South Pass have advanced more rapidly than those of lesser depth, and the western side of the bar has advanced more rapidly than the eastern.

The present sea slope at South Pass is about 1 in 93 out to the 90-foot depth, and at Southwest Pass about 1 in 75.

24. *Dredging.* Dredging in Southwest Pass has been carried on since 1905 by contractors using hydraulic pipe line dredges and by the United States hopper dredges. There are now employed on this work two large seagoing hopper dredges, belonging to the United States.

Extraordinary effort was made during the spring of 1916 to maintain the outer channel in Southwest Pass by dredging. The maximum amount of material dredged for any ten days during this time was 182,711 cubic yards, and for any one month 469,310 cubic yards. But the amount of bar-building material brought down by the river during the flood between March and June, 1916, was so great that, in spite of this dredging, there was actually 404,450 cubic yards more in June than in March to be removed to make the projected channel at the Gulf entrance. At times of great discharge and rising river, the sediment carried by Southwest Pass in one day approaches 2,000,000 cubic yards. The available depth in the outer channel was 25 feet in March, 19 feet in May, and 24 feet in June. Two dredges, and sometimes three, were operated during this time.

Approximately $3,700,000 has been expended on dredges and dredging.

The amount of dredging in South Pass has been small compared with that in Southwest Pass. About 6,400,000 cubic yards have been removed from South Pass by dredging with U. S. dredges. Between May, 1913, and November, 1915, there was no dredging in South Pass bar. However, since January, 1916, shoaling has greatly increased, and the amount actually removed from January to July, 1916, was over 900,000 cubic yards.

The following tabulated statement shows, in detail, the amount of dredging in lower portion of Southwest Pass, and what has been accomplished in channel development:

Date of Survey.	Material to be removed to make channel of project dimensions.	Amount removed by dredging. Cubic yards.	Scour. Cubic yards.	Deposit. Cubic yards.	Gain. Cubic yards.	Loss. Cubic yards.	Available depth, feet, M. L. W.	Carrollton gauge.
November, 1905	18,368,175						8	5.0
June, 1907	10,028,039	2,668,682	5,671,454		8,340,136		21	15.0
June, 1908	7,367,596	3,137,816		477,373	2,660,443		21	19.8
June, 1909	5,815,281	3,593,200		2,040,885	1,552,315		19	15.0
June, 1910	4,150,788	2,620,244		955,751	1,664,493		25	10.5
March, 1911	4,703,923	2,147,030		2,700,165		553,135	31	10.0
June, 1911	4,634,508	1,006,184		936,769	69,415		30	3.0
December, 1911	4,182,350	2,060,850		1,608,692	452,158		30	5.0
April, 1912	3,047,400	731,387	403,563		1,134,950		26	18.0
June, 1912	2,504,847	684,945		142,392	542,553		30	15.0
November, 1912	3,040,700	1,746,986		2,282,839		535,853	31	2.0
March, 1913	2,723,334	914,738		597,372	317,366		27	13.5
June, 1913	2,668,200	875,145		820,011	55,134		31	10.0
December, 1913	2,456,841	823,766		612,407	211,359		31	4.0
March, 1914	3,362,389	958,026		1,863,574		905,548	31	9.0
June, 1914	4,445,260	972,350		2,055,221		1,082,871	30	7.0
October, 1914	3,490,470	1,359,490		404,700	954,790		31	2.0
March, 1915	5,123,517	1,224,870		2,857,917		1,633,047	26	15.0
June, 1915	5,737,400	1,221,792		1,835,675		613,883	27	13.0
December, 1915	7,263,700	1,824,431		3,350,731		1,526,300	28	6.0
March, 1916	5,360,470	716,024	1,187,206		1,903,230		26	20.0
June, 1916	5,140,870	1,157,711		938,111	219,600		24	10.5
Total		32,445,667	7,262,223	26,480,585	20,077,942	6,850,637		

An analysis of this table shows that since 1905 there has been removed by dredging 32,445,667 cubic yards, and by scour 7,262,223 cubic yards, or a total of 39,707,890 cubic yards. The net gain in the amount of material to be removed to make the projected channel is 13,227,305 cubic yards; in other words, there has been deposited in the channel 26,480,585 cubic yards over and above all measured removal, or the quantity actually dredged is 19,218,362 cubic yards more than the net gain in project dimensions.

25. *Existing works at Southwest Pass, and present conditions.* The width between banks at Southwest Pass ranges from about 6,000 feet at the inner portion of the jetties to 1,190 feet in the fourth mile from the head, the average width being about 2,000 feet. The depth of water ranges from 30 feet to 85 feet, depending on the width between banks. A natural channel, having the project dimensions, is found in the twelfth mile from the head; the average width between banks in this portion of the Pass is approximately 2,500 feet.

The existing regulation works at Southwest Pass consist of two converging jetties having a width between them at the inner end of 6,000 feet, decreasing to 3,000 feet at the outer end. The jetties are supplemented by 14 spur dikes placed along the jetties and banks of the Pass. These dikes reduce the width between jetties to about 3,000 feet. The side outlets from the Pass were closed and mattress sills placed across the outlets above the Head of Passes. There has been expended to July 1, 1916, on these regulation works, approximately \$5,240,000 on jetty construction and maintenance, including equipment and floating plant, and \$3,700,000 for dredging, the exact total being \$8,939,003.31.

The substructure of the original jetties and the extensions consisted of tiers of brush mattresses; the first, or foundation tier, was 100 feet wide at the shore end of the jetties, and was 150 feet wide for a 10-foot depth and greater. Upon the foundation mattress were placed other mattresses, ranging in width from 95 feet for the second tier to 35 feet for the top tier near the water surface, the widths decreasing in each tier by 20 feet. The mattresses consisted of three layers of willows, the middle layer at right angles to the one above and below, held together and compressed with a wooden frame. The mattresses were constructed in 200-foot lengths, towed to the site, and secured in place in the jetty with stone ballast; each tier of mattresses breaking joints with the one above and below.

PLATE 13

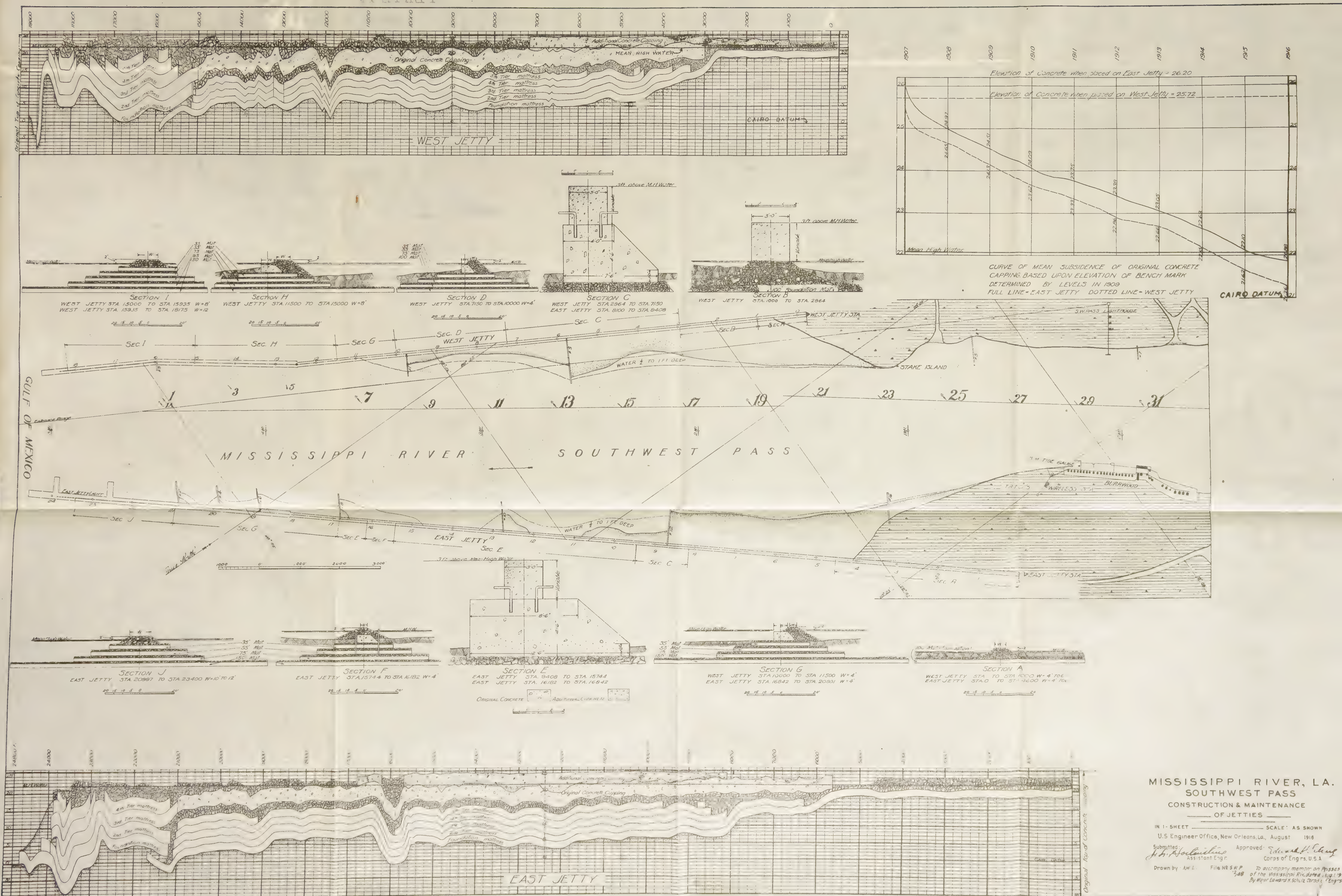

WEST JETTY
Additional Concrete Capping
Original Concrete Capping
MEAN HIGH WATER
5th Tier mattress
4th Tier mattress
3rd Tier mattress
2nd Tier mattress
Foundation mattress
CAIRO DATUM
Elevation of Concrete when placed on East Jetty = 26.20
Elevation of Concrete when placed on West Jetty = 25.72
Mean High Water
CURVE OF MEAN SUBSIDENCE OF ORIGINAL CONCRETE
CAPPING BASED UPON ELEVATION OF BENCH MARK
DETERMINED BY LEVELS IN 1909
FULL LINE = EAST JETTY DOTTED LINE = WEST JETTY
CAIRO DATUM
SECTION I
WEST JETTY STA. 15000 TO STA. 15935 W=8'
WEST JETTY STA. 15935 TO STA. 18175 W=12'
SECTION H
WEST JETTY STA. 11500 TO STA. 15000 W=8'
SECTION D
WEST JETTY STA. 7150 TO STA. 10000 W=4'
SECTION C
WEST JETTY STA. 2964 TO STA. 7150
EAST JETTY STA. 8100 TO STA. 9408
SECTION B
WEST JETTY STA. 1000 TO STA. 2964
3ft above M.H.Water
WEST JETTY STA.
S.W. PASS LIGHTHOUSE
STAKE ISLAND
WATER ½ TO 1 FT DEEP
GULF OF MEXICO
MISSISSIPPI RIVER SOUTHWEST PASS
EAST JETTY LIGHT
EAST JETTY
WATER ½ TO 1 FT DEEP
BURRWOOD
WIRELESS STA.
EAST JETTY STA.
SEC. A
SEC. C
SEC. E
SEC. F
SEC. G
SEC. J
3 ft above Mean High Water
SECTION J
EAST JETTY STA. 20997 TO STA. 23400 W=10' TO 12'
SECTION F
EAST JETTY STA. 15744 TO STA. 16182 W=4'
SECTION E
EAST JETTY STA. 9408 TO STA. 15744
EAST JETTY STA. 16182 TO STA. 16842
ORIGINAL CONCRETE
ADDITIONAL CONCRETE
SECTION G
WEST JETTY STA. 10000 TO STA. 11500 W=4'
EAST JETTY STA. 16842 TO STA. 20991 W=4'
SECTION A
EAST JETTY
4th Tier mattress
3rd Tier mattress
2nd Tier mattress
Foundation mattress
Original Concrete Capping
Additional Concrete Capping
MISSISSIPPI RIVER, LA.
SOUTHWEST PASS
CONSTRUCTION & MAINTENANCE
OF JETTIES
IN 1 - SHEET
SCALE: AS SHOWN
U.S. Engineer Office, New Orleans, La., August 1916
Submitted:
Assistant Engr.
Approved:
Corps of Engrs, U.S.A.
Drawn by: A.W.L.
File Nº S.W.P. 48
To accompany memo on Passes of the Mississippi River dated Aug. 1915 by Major Edward H. Schulz Corps of Engrs.

PLATE 18

On the top tier of mattresses in the jetties completed in January, 1908, was placed a layer of small stone 18 feet in width, with the top surface brought to about mean high water, and upon this stone as a base was placed a superstructure of concrete capping, composed of blocks 12 feet in length, 4½ feet in height, with a crown and base width of 4 and 7½ feet, respectively, for the inner portion, increasing to 8½ and 12 feet for the outer and more exposed portion. The concrete was moulded in place on the jetties.

The superstructure on the extensions of the jetties made in 1909 to 1912, consisted of capping stone placed upon the top tier of mattresses. The stone formed a wall 16 feet in width, natural side slopes, and the top brought to an elevation of 2 feet above mean high water. The capping stone varied in weight from 75 to 2,000 pounds per stone, and the larger stone was placed on the slopes and crown, and the small stone formed the hearting. This construction was used instead of concrete on account of the exposure of the extensions to heavy seas, which made it impracticable to mould concrete in place on the jetty.

The spur dikes consist of two, and sometimes three, rows of piles connected by waling timbers, braced transversely. The space between the rows of piling is then filled with willows weighted with stone. The combined length of the dikes is 8,685 linear feet.

Southwest Pass has been deteriorating since December, 1912, at which time there was an available depth at mean low water of 35 feet and the amount of material to be removed to make the channel of project dimensions was approximately 3,000,000 cubic yards. The controlling depths since then have ranged from 19 to 32 feet, and there is now approximately 5,140,000 cubic yards of material to be removed to make the projected channel, in spite of the fact that the dredges have removed 13,000,000 cubic yards during this time; in other words, there has been a deposit of 15,000,000 cubic yards of sediment in the lower 7½ miles of channel since December, 1912, of which amount the dredges have removed 13,000,000 cubic yards. The jetties and spur dikes have been effective with the exception of the high water season of 1914, when a portion of the water escaped over the outer portion of the jetties at high tide. The jetties were subsequently raised and made effective. The average annual subsidence of the jetties has been approximately ½ foot since they were completed.

(For general plane of present structures at Southwest Pass, see Plate 18.)

26. *Existing works at South Pass, and present conditions.* The width between banks in South Pass ranges from 600 to 800 feet, and the depth from 40 to 109 feet. The depths are too great for the width between banks, and as a result of this condition the banks are caving.

The existing regulation work at South Pass consists of two parallel jetties spaced 1,000 feet apart, and these are supplemented by inner jetties 650 feet apart, which are protected on the channel side by short spur dikes, and the inner and main jetties are connected with spur dikes. Spur dikes were also placed along the banks in the main body of the Pass where needed. The original regulation works at the Head of Passes, constructed in connection with improvement of South Pass, consisted of mattress sills across Pass a Loutre and Southwest Pass and training dikes between South Pass and Pass a Loutre and between South and Southwest Passes. The side outlets in South Pass were also closed. The cost of the work performed by James B. Eads amounted to $8,000,000, and in addition to this the United States has expended on maintenance and surveys about $1,800,000.

The jetties extended from the end-of-land on either side of the Pass out to the 20-foot depth contour. About 3,600 linear feet of the jetties at their seaward ends were built on a 1-degree curve, in order that the current would debouch from South Pass at an angle about normal to the alleged littoral current. The east jetty, measured along its foundation, was 12,070 feet long. This foundation was composed of mattresses, the width of which varied from 35 to 51 feet, according to depth of water. To build up to above water surface, other tiers of mattresses, with less width, were superposed. The number of tiers thus used varied from 1 to 11. The above-water length of the east jetty was 11,720 feet. For a distance of 5,150 feet from the origin, timber cribs were built on the foundation. For a distance of 2,237 feet from the seaward end, contiguous concrete blocks were moulded in place; these blocks were rectangular in cross-section, 4½ feet to 12 feet wide and about 3 feet to 4 feet high. Their top surface was 2¾ feet above average flood tide. In 1889, the east jetty, which had been greatly damaged by wave action, was repaired with new mattresses. Concrete blocks were built on the seaward 5,500 feet of the jetty. The wall thus formed was 3½ feet to 7 feet width of base, 1½ to 5 feet high, and had a slope on the seaward side. Its top was 2 feet to 3 feet above average flood tide.

The west jetty was of similar construction. Its foundation

length was 7,820 feet and above-water length 7,520 feet. It was composed of three to seven tiers of mattresses, with superposed concrete wall, as described above.

The inner jetties consisted simply of two parallel rows of piles 6 feet apart, with space between filled with willow brush laid in course having different directions. These jetties have since been widened to about 30 feet, the brush laid so as to form a slope on the seaward side, and only the row of piles nearest to the Pass maintained. The inner east jetty was 10,373 feet long and the inner west jetty 4,710 feet long.

The spur dikes consist of two rows of piles connected by waling timbers, braced transversely. The space between the rows of piling is then filled with willows weighted with stone.

During the past ten years the discharge through South Pass has increased about 53 per cent, and since 1898 about 60 per cent. This has caused the banks along the Pass to cave and the heavy sediment thrown out from the Pass has accelerated the large shoal on the western side of the channel at the sea entrance to the jetties, thus forcing the entrance channel to the eastward until it now makes an angle of 37 degrees with the jetties at their seaward end. The large amount of sediment deposited at the jetty entrance has resulted also in the formation of mud lumps in and near the channel, and these lumps, together with the easterly shifting of the channel, have made the navigation of the channel difficult for the large vessels.

(For general map of mouth of South Pass, see Plate 16.)

27. *Existing works at Head of Passes, and present condition.* The existing regulation works at the Head of Passes consist of a mattress sill across Pass a Loutre and training dikes between South Pass and Pass a Loutre, and between South Pass and Southwest Pass. The training dikes are partially protected against undermining by mattress work.

Extensive shoaling occurs at the Head of Passes and dredging the shoal has given only temporary benefit, as the dredged channel is rapidly filled each time a "sand wave" moves down the river, and these sand waves are of frequent occurrence, sometimes occurring during or after each high water season.

The regulation works at the Head of Passes have deteriorated, due to caving banks at and near the training dikes, the deepening of the river bed immediately below the western end of the Pass a Loutre sill, and the natural decay of the material in the dikes.

28. *Commercial statistics, Port of New Orleans.* A comparative

statement of foreign and domestic receipts and shipments, from 1910 to 1915, for the port of New Orleans, La., is as follows:

Calendar year.	Foreign.		Domestic.		Total.	
	Short tons.	Valuation.	Short tons.	Valuation.	Short tons.	Valuation.
		Dollars.		*Dollars.*		*Dollars.*
1910	3,202,777	216,358,440	761,332	44,778,197	3,964,109	261,136,637
1911	3,754,705	221,574,184	733,021	41,787,497	4,487,726	263,361,681
1912	4,273,947	254,112,010	785,883	45,338,717	5,059,830	299,450,727
1913	5,370,491	261,176,635	1,072,441	53,905,897	6,442,932	315,082,532
1914	5,053,060	260,708,811	1,219,952	50,849,050	6,273,012	311,557,861
1915	5,252,475	300,832,524	1,283,657	67,689,761	6,536,132	368,522,285

The above comparison shows that its foreign commerce has increased 38 per cent in value and about 60 per cent in tonnage in the last five years.

The domestic commerce in the same period has increased 69 per cent in tonnage and 52 per cent in value.

The combined foreign and domestic commerce has increased 66 per cent in tonnage and 41 per cent in value.

The "World Almanac" for 1916, page 226 (compiled by Department of Commerce), gives the value of foreign commerce for 1914 of various American ports as follows: New York, $1,904,926,-864; New Orleans, $283,222,582; Galveston, $268,012,670; Massachusetts, $225,631,151; Philadelphia, $161,665,926; Maryland, $144,179,725; and San Francisco, $130,485,990. This places New Orleans second.

PORT OF NEW ORLEANS, LA., COMMERCIAL STATISTICS.

Season of navigation, year 1915: Opened January 1, 1915; closed December 31, 1915.

Vessel Classification.

Class.	Number American.	Number Foreign.	Total.	Net registered tonnage.	Passengers
Registered:					
Steamers	713	2,322	3,035	6,034,788	20,768
Sailing	8	42	50	51,921	--------
Coastwise steamers	460	312	772	2,116,584	20,000
Unrigged barges	34	6	40	53,084	--------
Unregistered:					
Unrigged barges	60	--------	60	----------	--------
Total clearances and arrivals	1,275	2,682	3,957	8,256,377	40,768

Articles.	Year ending Dec. 31, 1915.	
	Tons.	Value.
Foreign exports and imports.		
EXPORTS		
All animals	204,601	$20,460,064
Flour	216,856	13,479,674
Wheat	899,117	40,578,739
Cotton and manufactures of cotton	400,937	74,526,442
Logs, boards, etc.	414,667	4,976,011
Lard and lard compounds	29,355	6,103,601
Mineral oils, refined	290,246	4,643,943
Oils, illuminating	462,903	5,368,178
Tobacco	41,213	10,097,267
General miscellaneous	804,716	38,640,534
Total exports	3,764,611	$218,874,453
IMPORTS.		
Bananas	376,200	$4,703,639
Coffee	168,818	31,082,828
Oils, all kinds	337,825	2,702,604
Sisal grass	88,590	10,217,923
Sugar	249,136	17,700,735
General miscellaneous	267,295	15,550,342
Total imports	1,487,864	$81,958,071
Total exports and imports	5,252,475	$300,832,524
Domestic shipments and receipts.		
SHIPMENTS.		
Bullion, lead, zinc and copper	32,391	$10,203,165
Cotton	62,121	10,424,200
Oil, fuel	495,661	3,965,288
Rice	36,585	2,766,000
Sugar	23,974	2,397,400
General miscellaneous	269,030	15,904,072
Total shipments	919,762	$45,660,125
RECEIPTS.		
Fertilizer	40,194	$1,205,820
Iron and steel	19,783	989,150
Oil, fuel	30,893	247,144
Oil, refined	73,040	2,410,320
General miscellaneous	199,985	17,177,202
Total receipts	363,895	$22,029,636
Total shipments and receipts	1,283,657	$67,689,761
Total foreign, in and out	5,252,475	$300,832,524
Total domestic, in and out	1,283,657	67,689,761
Grand total	6,536,132	$368,522,285

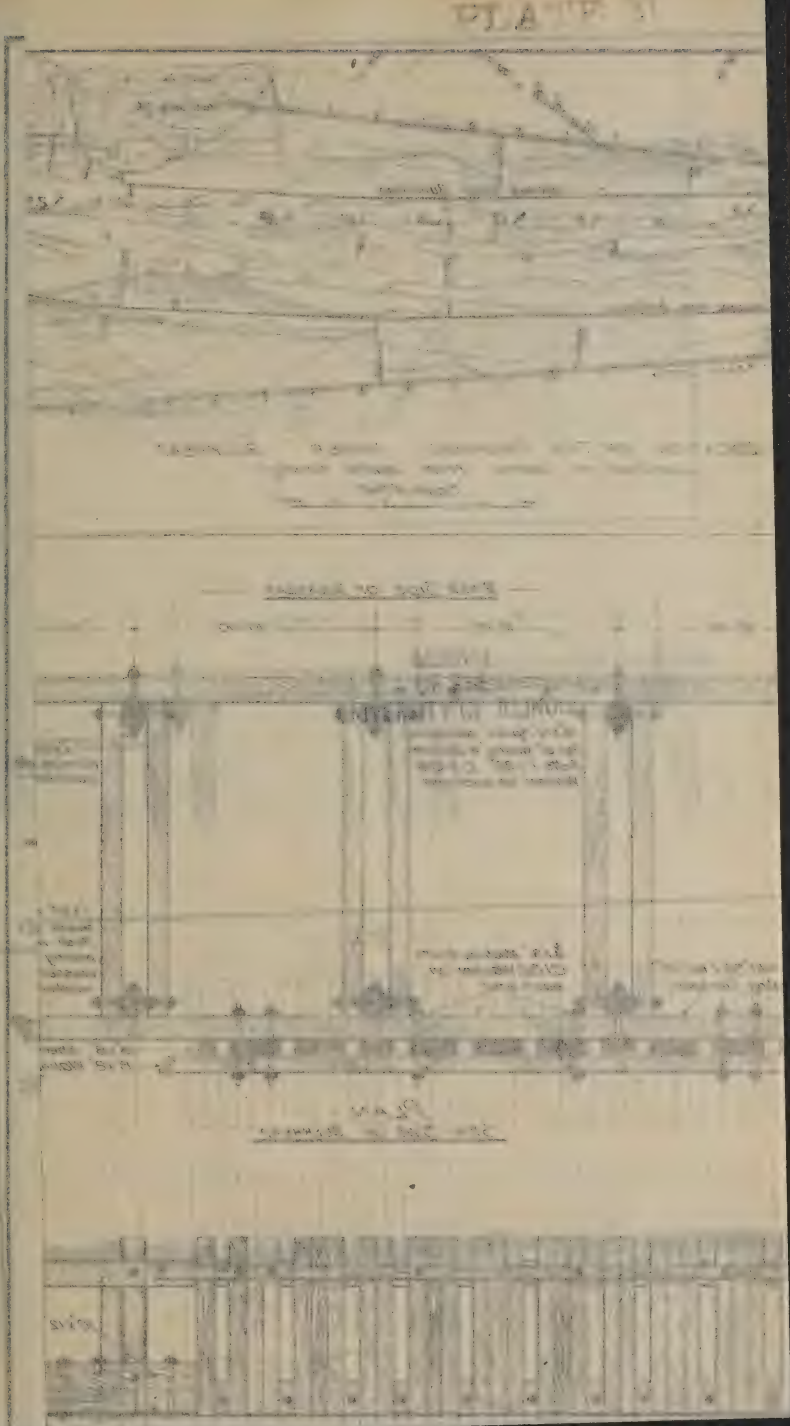
29. *Work needed at Southwest Pass, and estimate.* (See Plates 21 and 23.) The following works are considered necessary to secure a channel of the project dimensions through Southwest Pass.

(*a*) Parallel inner jetties or bulkheads in the lower portion of the Pass to hold the banks and deposited material and to confine and direct the flow into the Gulf, distance between jetties to be 2,400 feet. The bulkhead is to consist of two rows of round piling connected by waling timbers and braced transversely. Against the land side of this cribwork a row of square sheet piling is to be driven and securely bolted to the waling timbers. The revetment is to be protected against scour by constructing short spur dikes along the channel side to fend the current away and, where found necessary, the dikes are to be supplemented with mattresses laid along the revetment. The piling and connecting timbers are to be creosoted pine. The bulkheads are to be about 52,250 linear feet in length, of creosoted sheet piling, complete, including short spurs of mattress work where necessary. (For general plans, see Plate 21.) The estimated cost is $2,000,000.

(*b*) Extension of existing spur dikes to join the inner jetties where necessary, and establishment of new spur dikes opposite Burrwood; estimated total length, 12,000 linear feet. Spur dikes are to be similar to those now in use at Southwest Pass and to be of creosoted piles and timber, and willows and stone with protection mats at ends where necessary. The estimated cost is $350,000.

(*c*) Extension of main jetty along parallel lines, 2,400 feet apart, to be similar to previous extensions at Southwest Pass. The work is to consist of a substructure of brush mattresses and a superstructure of stone capping brought to an elevation of 2 feet above high tide. The superstructure is to be about 16 feet in width, natural side slopes, and composed of stone ranging in size from 1,000 to 8,000 pounds; concrete capping blocks are also to be used where practicable. All foundation mattresses are to be put into place in the jetties during a comparatively low stage of river, in order to prevent scour. The depth of water in which the extensions are placed varies from 15 to 27 feet. The west jetty is to be extended for a distance of about 1,900 feet and the east jetty for about 2,200 feet. The estimated cost is $675,000. (See Plate 23.)

(*d*) Operation of pipe-line dredge in the inner channel to hasten channel development and prevent, as far as practicable, any unnecessary disturbances in the existing equilibrium of the Pass; the dredged material to be deposited back of the inner jetties to strengthen them. Operation of two seagoing dredges in the outer channel and the operation of the present shore plant at Burrwood, as follows:



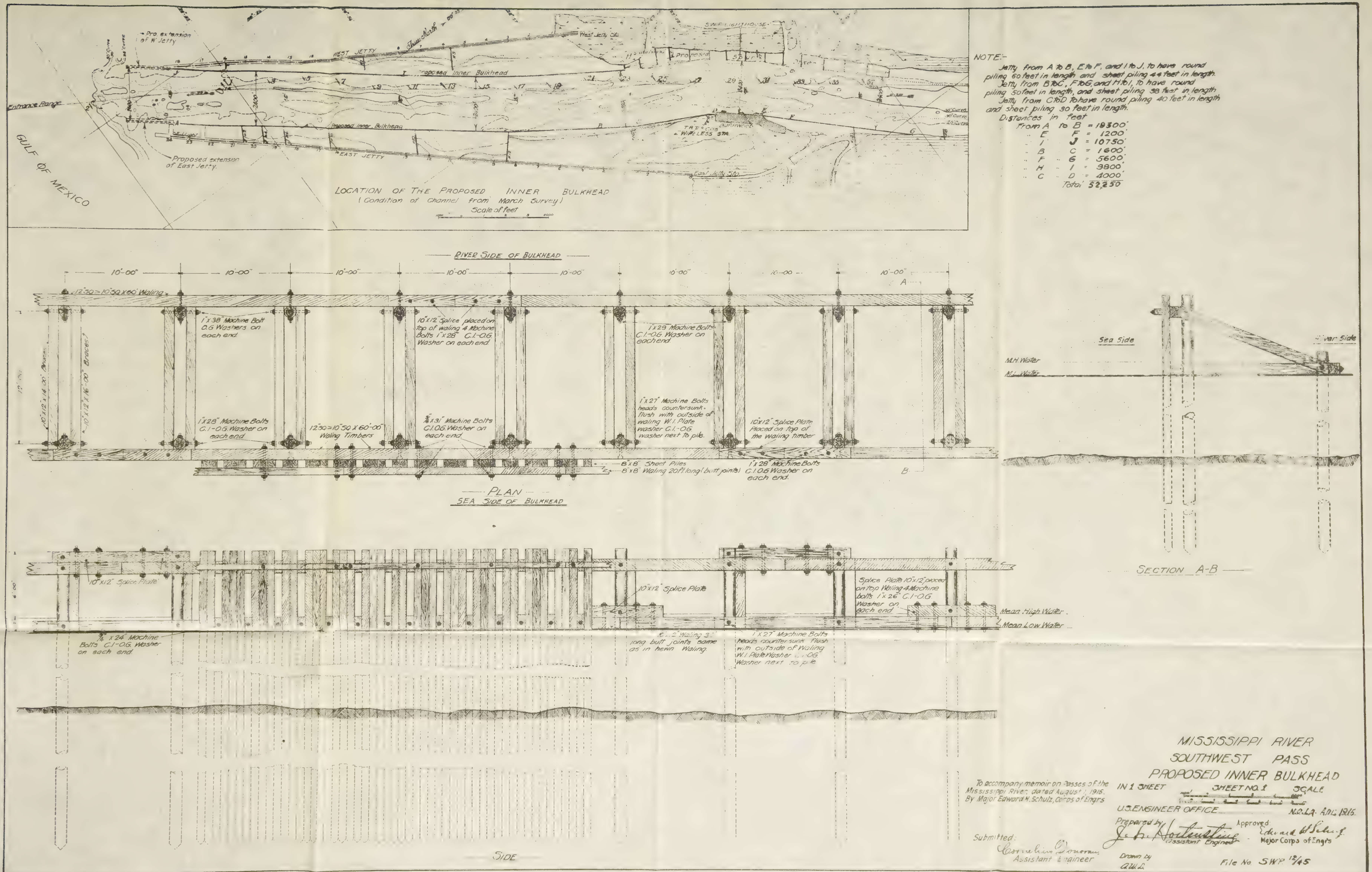
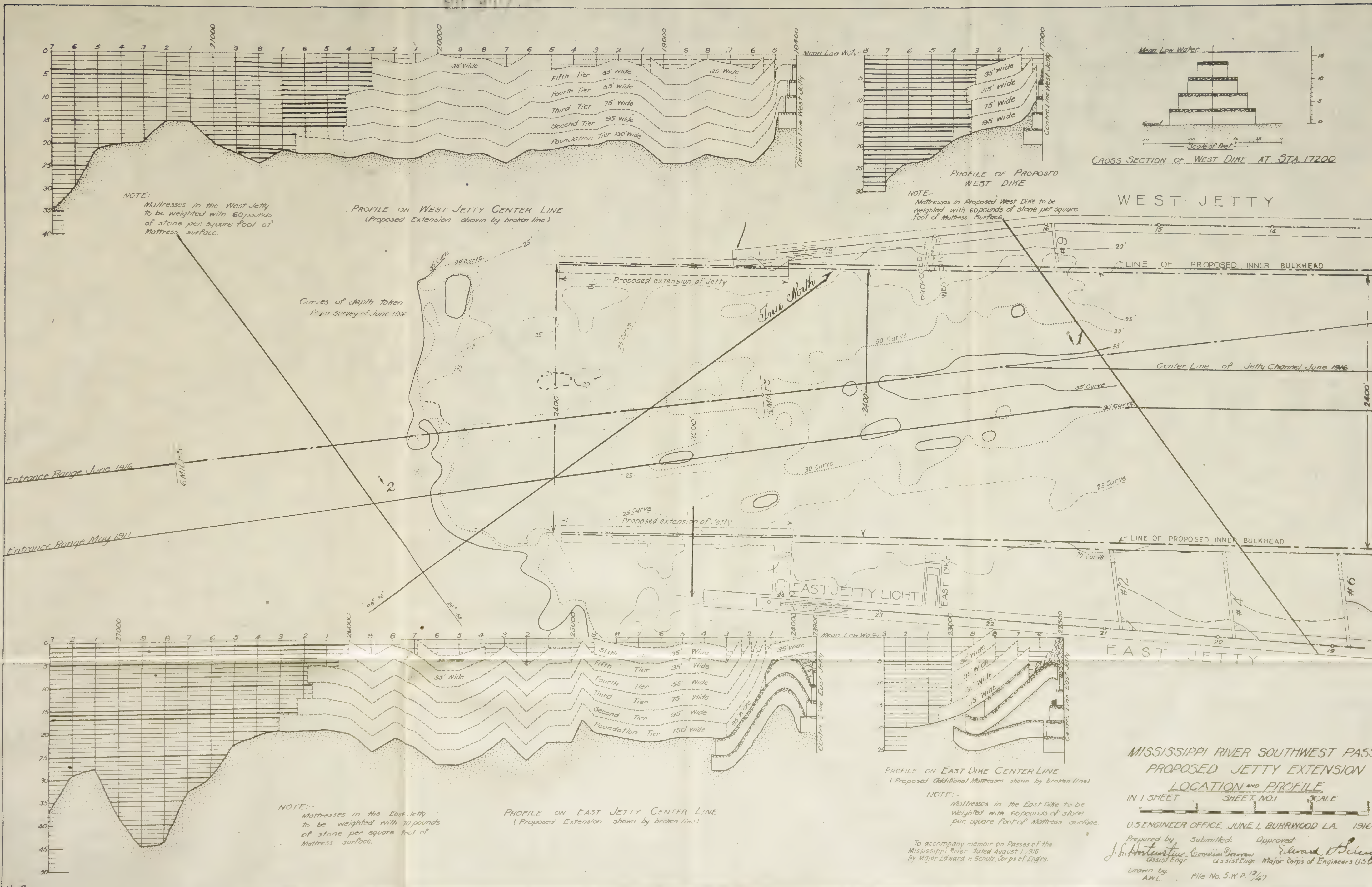

GULF OF MEXICO
Pro. extension of W. Jetty
WEST JETTY
True North
West Jetty Sta.
S.W.P. LIGHTHOUSE
Proposed Inner Bulkhead
Entrance Range
Proposed Inner Bulkhead
EAST JETTY
T.R.P.C. WIRELESS STA.
East Jetty Sta.
Proposed extension of East Jetty.
LOCATION OF THE PROPOSED INNER BULKHEAD
(Condition of channel from March Survey)
Scale of feet
NOTE:-
Jetty from A to B, E to F, and I to J, to have round piling 60 feet in length and sheet piling 44 feet in length.
Jetty from B to C, F to G, and H to I, to have round piling 50 feet in length, and sheet piling 38 feet in length.
Jetty from C to D to have round piling 40 feet in length and sheet piling 30 feet in length.
Distances in feet
From A to B = 19300'
" E " F = 1200'
" I " J = 10750'
" B " C = 1600'
" F " G = 5600'
" H " I = 9800'
" C " D = 4000'
Total 52,250
RIVER SIDE OF BULKHEAD
10'-00"
12"x30 = 10'-30 x 60' Waling
1"x38" Machine Bolt O.G. Washers on each end
10"x12" Splice placed on top of waling 4 Machine Bolts 1"x28" C.I.-O.G. Washer on each end
1"x29" Machine Bolts C.I.-O.G. Washer on each end
1"x27" Machine Bolts heads countersunk flush with outside of waling W.I. Plate washer C.I.-O.G. washer next to pile.
10"x12" Splice Plate Placed on top of the waling timber
1"x28" Machine Bolts C.I.-O.G. Washer on each end
12"x30 = 10"x30 x 60'-00" Waling Timbers
7/8"x31" Machine Bolts C.I.O.G. Washer on each end.
8"x8" Sheet Piles
8"x8" Waling 20 ft. long (butt joints)
1"x28" Machine Bolts C.I.O.G. Washer on each end.
PLAN
SEA SIDE OF BULKHEAD
Sea Side
River Side
M.H. Water
M.L. Water
SECTION A-B
10"x12" Splice Plate
10"x12" Splice Plate
Splice Plate 10"x12" placed on top Waling 4 Machine bolts 1"x26" C.I.-O.G. Washer on each end
Mean High Water
Mean Low Water
7/8"x24" Machine Bolts C.I.-O.G. Washer on each end.
Waling 3' long butt joints same as in hewn Waling
1"x27" Machine Bolts heads countersunk flush with outside of Waling W.I. Plate Washer C.I.-O.G. Washer next to pile
SIDE
MISSISSIPPI RIVER
SOUTHWEST PASS
PROPOSED INNER BULKHEAD
To accompany memoir on Passes of the Mississippi River, dated August 1, 1916. By Major Edward H. Schulz, Corps of Engrs
IN 1 SHEET
SHEET NO. 1
SCALE
U.S. ENGINEER OFFICE
N.O. LA. AUG. 1916.
Prepared by J. L. Hortenstine Assistant Engineer
Approved: Edward H. Schulz Major Corps of Engrs
Submitted: Cornelius O'Donovan Assistant Engineer
Drawn by A.W.L.
File No. SWP 12/45

PLATE 21

PLATE 23



PROFILE ON WEST JETTY CENTER LINE
(Proposed Extension shown by broken line)
NOTE:- Mattresses in the West Jetty to be weighted with 60 pounds of stone per square foot of Mattress surface.
Mean Low Water
Fifth Tier 35' wide
Fourth Tier 55' wide
Third Tier 75' wide
Second Tier 95' wide
Foundation Tier 150' wide
Centre Line West Jetty
PROFILE OF PROPOSED WEST DIKE
NOTE:- Mattresses in Proposed West Dike to be weighted with 60 pounds of stone per square foot of Mattress Surface.
Mean Low Water
Scale of Feet
CROSS SECTION OF WEST DIKE AT STA. 17200
WEST JETTY
LINE OF PROPOSED INNER BULKHEAD
Proposed extension of Jetty
PROPOSED WEST DIKE
True North
Curves of depth taken from survey of June 1916
Center Line of Jetty Channel June 1916
Entrance Range June 1916
Entrance Range May 1911
6 MILES
5 MILES
Proposed extension of Jetty
LINE OF PROPOSED INNER BULKHEAD
EAST JETTY LIGHT
EAST DIKE
EAST JETTY
PROFILE ON EAST JETTY CENTER LINE
(Proposed Extension shown by broken line)
NOTE:- Mattresses in the East Jetty to be weighted with 70 pounds of stone per square foot of Mattress surface.
Sixth Tier 35' Wide
Fifth Tier 35' Wide
Fourth Tier 55' Wide
Third Tier 75' Wide
Second Tier 95' Wide
Foundation Tier 150' Wide
Centre Line East Jetty
PROFILE ON EAST DIKE CENTER LINE
(Proposed Additional Mattresses shown by broken line)
NOTE:- Mattresses in the East Dike to be weighted with 60 pounds of stone per square foot of Mattress surface.
To accompany memoir on Passes of the Mississippi River dated August 1, 1916 By Major Edward H. Schulz, Corps of Engrs.
MISSISSIPPI RIVER SOUTHWEST PASS
PROPOSED JETTY EXTENSION
LOCATION AND PROFILE
IN 1 SHEET SHEET NO. 1 SCALE
U.S. ENGINEER OFFICE. JUNE 1, BURRWOOD LA. 1916
Prepared by Submitted: Approved:
J. S. Hortenstine Cornelius Donovan Edward H. Schulz
Assist Engr Assist Engr Major Corps of Engineers U.S. Army
Drawn by A.W.L. File No. S.W.P. 12/47
No. 3

PLATE 23

Rental of dredge with tug and two years' dredging	$275,000
(*e*) Operation of two seagoing dredges for two years	400,000
(*f*) Engineering, superintendence, and contingencies, and maintenance of plant and existing works for two years	510,000
Total	$1,185,000

Grand total for necessary work in lower portion of Southwest Pass, $4,210,000.

30. *Work needed at South Pass, and estimate.* Caving banks along the Pass, where there is danger of crevasse, are to be repaired and protected with mattresses; existing dikes and jetties are to be maintained in an effective condition; and dredging is to be done in the outer channel to maintain the necessary depth for the large vessels until such time as Southwest Pass can accommodate them. Any necessary extension of jetties would be very difficult and cost about one and a half million dollars. The extension of the South Pass jetties is not recommended at this time, for the reason that dredging will give temporary relief, and for the further reason that to extend the jetties in a direction to secure a straight channel will cause the east jetty extension to cross the existing deep channel; while, on the other hand, if the jetties are extended along lines approximately parallel to the existing channel, a comparatively sharp curve will be put in the alignment of the jetties, which will cause the vessels to change direction by as much as 39 degrees in navigating the jetty channel. Such a condition will render navigation difficult for large vessels and is therefore, at present, not considered advisable.

To carry on the work of protecting and repairing caving banks and necessary dredging at the bar at South Pass, the annual appropriation of $100,000 should be increased by an additional $150,000 for at least two years.

31. *Work needed at Head of Passes, and estimate.* The work now authorized and to be placed at once is as follows: Sill across head of South Pass and revetment of banks at the headlands between South and Southwest Passes, and South Pass and Pass a Loutre, at an estimated cost of $230,000.

In addition to this work, spur dikes should be constructed to further confine and direct the flow into the Passes. These dikes should be similar to those previously built at Southwest Pass. The estimate for eleven dikes of 4,850 linear feet is $160,000.

32. *Summary and estimate of work for Southwest Pass and Head of Passes:*

Construction of spur dikes at Head of Passes	$160,000
Sill across head of South Pass, and repairs to Pass a Loutre sill and revetment at Head of Passes	230,000
Spur dikes, vicinity of Burrwood, Southwest Pass	350,000
Inner bulkheads and protection of same	2,000,000
Extension of jetties, Southwest Pass	675,000
Dredging within jetties, Southwest Pass	275,000
Dredging on bar	400,000
	$4,090,000
Engineering, superintendence and contingencies, and maintenance during construction	510,000
Total	$4,600,000

The total amount now considered necessary, namely, $4,600,000, when added to the $8,940,000 already expended on present project, is not much greater than the original estimate of the 1898 Board, and if maintenance since 1905 is considered, it is really less.

33. *Urgency of improvements at Southwest Pass, and order of work.* The maximum benefit can be obtained only by a rapid construction of the works, and it is therefore recommended that immediately the funds are available that work be started and that it be prosecuted with utmost vigor, and should be completed within three years from the time of commencement.

The balance now available from the appropriation of July 27, 1916, after providing for the necessary hopper dredging and maintenance, is $550,000, exclusive of the $230,000 for work at Head of Passes, which has already been provided for.

The following order of work is suggested:

Work.	1st year. Fiscal year 1917 (Available.)	2d year Fiscal year 1918	3d year Fiscal year 1919	Total.
Head of Passes	$230,000	----------	----------	$230,000
Spur dikes, Head of Pass	----------	----------	$160,000	160,000
Bulkhead, Southwest Pass	450,000	$1,300,000	250,000	2,000,000
Jetty extension, Southwest Pass	----------	250,000	425,000	675,000
Spur dikes, Southwest Pass	*50,000	----------	300,000	350,000
Dredging (hopper) Southwest Pass	----------	200,000	200,000	400,000
Dredging (pipe line) Southwest Pass	*50,000	50,000	175,000	275,000
Miscellaneous	----------	200,000	310,000	510,000
Total	$780,000	$2,000,000	$1,820,000	$4,600,000

*Necessary the first year in connection with beginning inner bulkhead.

The above order, proportion of work, and division of estimate are subject to changes as the work progresses, and as conditions may develop, and authority to make necessary modifications should be given.

The Methods of Levee Location.[1]

BY

Mr. W. E. KNOBLOCH,
Assistant Engineer.

Under resolutions of the Mississippi River Commission, each new levee built on the Mississippi River above New Orleans is located on a line which will give the levee a life of at least twenty-five years; below New Orleans, where there is but a narrow strip of cultivable and very valuable land, and where the cost of a new levee is small on account of its low height and small cubical contents, a new levee is located to have a life of at least ten years and so as to leave at least 150 feet of batture between the river toe of the levee and the zero contour of the shore.

Below New Orleans there seldom arises any condition to be considered other than the distance between the toe of the levee and the zero contour of the shore; for there are few places where the bank caves at a rate of as much as 15 feet a year, and, as the land slopes away from the river, the nearer the levee is built to the edge of the bank the smaller is the cost.

In locating a new levee above New Orleans many things should be considered, viz: Its life, its cost, the value of property destroyed, the character of the foundation upon which it is built, and the material available for its construction.

The life of twenty-five years is determined:

(*a*) By taking a series of comparative bank lines at intervals of about a year. Thus the rate of caving is determined.

(*b*) By studying the caving to find out whether the rate of caving will increase or diminish. Care must be taken to ascertain whether the bank caves periodically or regularly. (Some banks cave periodically, at intervals sometimes as great as five years.

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[1]With comments by Maj. W. G. Caples, Corps of Engineers, District Officer, and Col. C. McD. Townsend, Corps of Engineers, President Mississippi River Commission.

(*c*) By observing changes in the bank for about 4 or 5 miles above the proposed new levee and observing what changes are occurring that might cause changes in the bank at the site of the proposed new levee. If the bank above is making out to the river and the making bank is working downstream, eventually the bank in front of the site of the proposed new levee will be either stationary or making.

After taking these observations, the future annual rate of the recession of the caving bank is estimated. The new levee line is then located so as to have its nearest point at a distance from the edge of the bank at least twenty-five times the rate of bank recession, plus a distance for a factor of safety. The margin for a factor of safety varies with the rate of caving or with the manner of caving. Where the bank caves regularly, the margin is 1¼ (for small levees) to 2 (in large levees) times the rate of recession; but, where the bank caves periodically, the margin is decided upon by the time of the last cave and the shape of the bank. If a cave has just occurred and a deep curve is in the bank, the same margin is used as in a case where the bank caves regularly; but, if the cave has not been recent and the bank has straightened out, instead of having curved pockets in it, at least three or four times the rate of caving must be added for the margin of safety.

After having decided where a levee can be located to give it the desired life, the other conditions are determined.

Cost. The cost is dependent upon the elevation of the ground upon which the levee is to be built, the facilities of construction, such as clearing base, draining borrow pits, and length of haul where teams are employed. Often the land next to the edge of the bank is low swamp and of very small value. In such a case, often, by going much farther back than the line of a twenty-five year life, a longer line can be built at a lower cost. Often the cubical contents, as well as the cost per cubic yard, are reduced.

Value of property destroyed. In cases where a new levee could be built on a line farther removed from the edge of the bank than the line for twenty-five year life at much lower cost, the value of the property destroyed must be considered. Where the destroying of buildings, railroads, etc., is involved, not only must the value of the land be considered, but also the cost of removing and relocating of such structures must be considered. Where the difference in cost of the levee on a farther removed line over that of the line of twenty-five year life is less than the value of the property destroyed, the twenty-five year life line must be selected; but

where the difference in cost is greater than the value of the property destroyed, the levee of the least cost is, as a matter of course, selected.

Character of foundation. Two things are to be considered in the foundation:

(*a*) Whether there is danger of a blow-out in the foundation during high water on account of a sandy foundation or on account of voids in the foundation caused by the decay of perishable matter. (This last condition sometimes exists in beds of old bayous which have been filled with a deposit of sand.)

(*b*) Whether the foundation can sustain the weight of the levee without great subsidence.

Material. There is seldom much choice in the material available for the construction of a levee, and if the material is composed of not more than 60 per cent of pure sand, the material need not be considered in selecting the location. But if the material is all sand of recent deposit and, as often is the case in building a new levee where a crevasse has occurred, the cost of its removal and the cost of construction is not less than a levee located on a line where better material can be obtained, the location must be selected where suitable material can be procured.

Necessity for new levees. The caving of a bank is not the only thing that necessitates the construction of a new levee, for, often, new levees are built where the existing levee is not up to the standard grade and section and is too close to the edge of a stationary bank to allow its enlargement, and, frequently, existing levees which were constructed thirty or forty years ago have given trouble in high water on account of the manner in which they were built. In these cases, new levees are built on a location which, in the first case, is far enough away from the edge of the bank to allow obtaining enough material for its construction, and, in the second case, is just back of the existing levee.

COMMENTS *by* MAJ. W. G. CAPLES, *Corps of Engineers, District Officer.*

The subject of levee location in Louisiana is complicated by the fact that no payments are made for land taken for levee purposes, except in the parish of Orleans. Under the original grants, riparian lands are subject to perpetual easement for a road and a levee. The constitution of the State of Louisiana gives the United States equal rights with the State in levee matters and thereby

greatly cheapens and facilitates levee work. The right has to be exercised with discretion and no little tact, for it is in the power of the people concerned to withdraw this right and to abolish the easement, as has been done in the parish of Orleans, where property values are great. The custom is to balance property damage against construction costs and to adopt the line which gives the least total construction cost and property damage, subject, of course, to the line being a correct one from the standpoint of giving the required degree of safety.

Were the country uninhabited, the logical procedure would be to stabilize the banks of the river before building any levees, because of the great expense caused by the river's cutting into the levees and necessitating the construction of new lines. The country being inhabited, the best that can be done is to place the levees on "essentially permanent" locations. "Essentially permanent" locations have been taken to be ones which will give a 25-year life above New Orleans or a 10-year life below New Orleans. The concession below New Orleans is made because of the small size of the levees and the very narrow belt of tillable land between the river and the swamps. Practically, the location of the levees below New Orleans is determined by a condition, added at the instance of the writer, namely, that at least 150 feet of batture shall be left between the low-water surface of the river (commonly known as the zero contour) and the river toe of the levee. This condition is made because, without a belt of willows, about 150 feet wide, to check the force of drift, nothing short of a seawall can save the levees from destruction in one of the tropical storms that occur on an average of once every eight or ten years. Below New Orleans the banks rarely cave as much as 150 feet in ten years.

The conditions as to life of the levee apply to enlargements as well as to new levees. The rule in regard to enlargements is that if the cost of enlargement bears to the cost of a new levee the same or a less ratio than the life of the enlarged levee bears to the life required of a new levee, the levee may be enlarged.

Estimation of the probable life of a levee is not an easy task. The future action of the river must be judged by present and past performance. Sometimes the river changes its action radically and either gets to the levee too soon, or, more often, ceases caving and does not reach the old levee after a new one has been built. Where the engineer builds a new levee and the river fails to destroy the old one, the new levee is known by the name of its builder; as, "So-and-so's Folly." The list of those who have had levees named after them includes practically every engineer of prominence connected with the Louisiana levees during the past fifty years, and is sufficiently imposing to convince their successors that the science of levee location is yet far from exact. Really, a "Folly" levee is a success. Mistakes in the other direction are rarely charged against their makers, because the river soon removes the evidence and the mistake is forgotten.

The easiest problem in location is one where the river has been

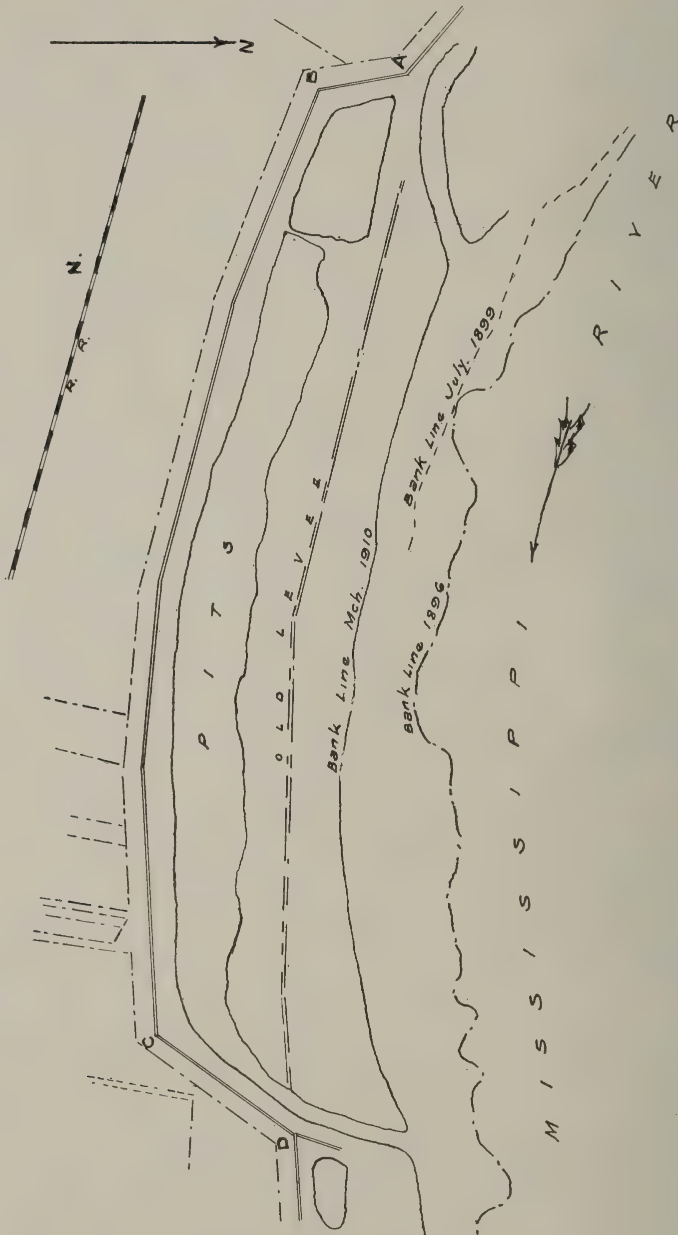


Fig. 1. Allendale Levee. A, B, C and D located on line of 25-year life. Scale, 1=15,000.

cutting at a uniform rate for a number of years. Unless there is evidence of a bar making downstream, it is generally safe to assume that the action of the river will continue uniform. A factor of safety varying from 1.25 to 2.0, depending upon the value of the levee, is used; that is to say, the levee is placed where the river apparently will not reach it from from 31 to 50 years. The most difficult problem is where the bank caves irregularly in what are known as "pocket caves." The river will take a great bite out of a bank of this kind. Then there will be but little active caving until the bank line has become regular from a process of slow caving. As soon as the bank line becomes regular, a new cave of considerable extent is to be expected. Such banks are very dangerous, as caves reaching back over 200 feet and taking out part of the levee during high water are not unknown. For these reasons, unless a cave has just occurred, a much larger factor of safety, from 3 to 4, is used. The writer would not recommend a factor less than 3 on such a bank in any case, but, because of property questions, it is customary to use a factor of 2 if the cave has just occurred. The movement of bars downstream has also to be considered. When a bar starts at the head of a bend and builds down the concave bank, it is an indication that the regimen of the stream is becoming at least temporarily stable in the bend concerned. The indication is, however, far from exact. When the rate of travel of the bar is balanced against the rate of caving of the bank, a high factor of safety, not less than 2.5, should be used.

Having made a calculation as to the probable action of the river, the line of 25-year life is drawn. No levee can be located closer to the river than this line. Below Bayou Sara the levee may frequently be located exactly on this line, because the land slopes fairly uniformly away from the river and presents about the same characteristics at one place as at another. Allendale Levee (Fig. 1) is a typical example of such a location. A location on the 25-year line will give the lowest levee—and consequently the cheapest to construct and easiest to maintain—if the ground slopes uniformly away from the river. To a slightly greater extent above Bayou Sara and markedly so above Red River, the problem is complicated by swamps and ridges. Kempe Levee (Fig. 2) is an example. The line of 25-year life falls in a swamp, where construction would be expensive and a high levee would be required. Back of this swamp is a ridge, where construction would be simpler and the levee would be lower. Property questions are not involved, as the land is all worthless or of little value. The longer line, being cheaper both to build and to maintain, is preferable.

The lines possible from the standpoints of efficiency and economy having been selected, property questions are next considered. Since no payment is made for the land, the owner is entitled to the utmost consideration. If the value of the property taken exceeds the difference in cost between any two lines, the more expensive line is justifiable. On the other hand, the cost of construction

must be no greater than warranted by the value of the property. Greens Levee (Fig. 3) is an example. The line of 25-year life is a long one through heavy woods, where construction is expensive. A levee built on that line would leave a long loop inclosing land of very small value. The preferable location is DNMF, which gives a levee costing enough less than one on the line ABC to more than counterbalance the value of the land in the area included between the two lines and the old levee thrown out from A to K. Lines of excessive cost and those throwing out valuable property or important means of communication, like railways, are rarely built. The preferable and generally adopted method is to revet the bank.

Fig. 2. Kempe Levee. A, B, C and D, line of 25-year life. K, L, M, O and P, line of less cost, throwing out swamp lands of small value. Note: figures on line, elevation referred to Cairo Datum. Scale, 1=80,000.

There is one feature in connection with any levee location that has always been important, but with the increased height of floods has become of supreme importance; that feature is the foundation. During the early history of levee building the basins above Louisiana were open and acted as great reservoirs; in fact, they formed the only possible effective reservoir system for the Lower Mississippi. Levee work was disorganized. Although the floods were of moderate height, the great problem was to get levees high enough. A levee overtopped by a stream of water is certain to be destroyed.

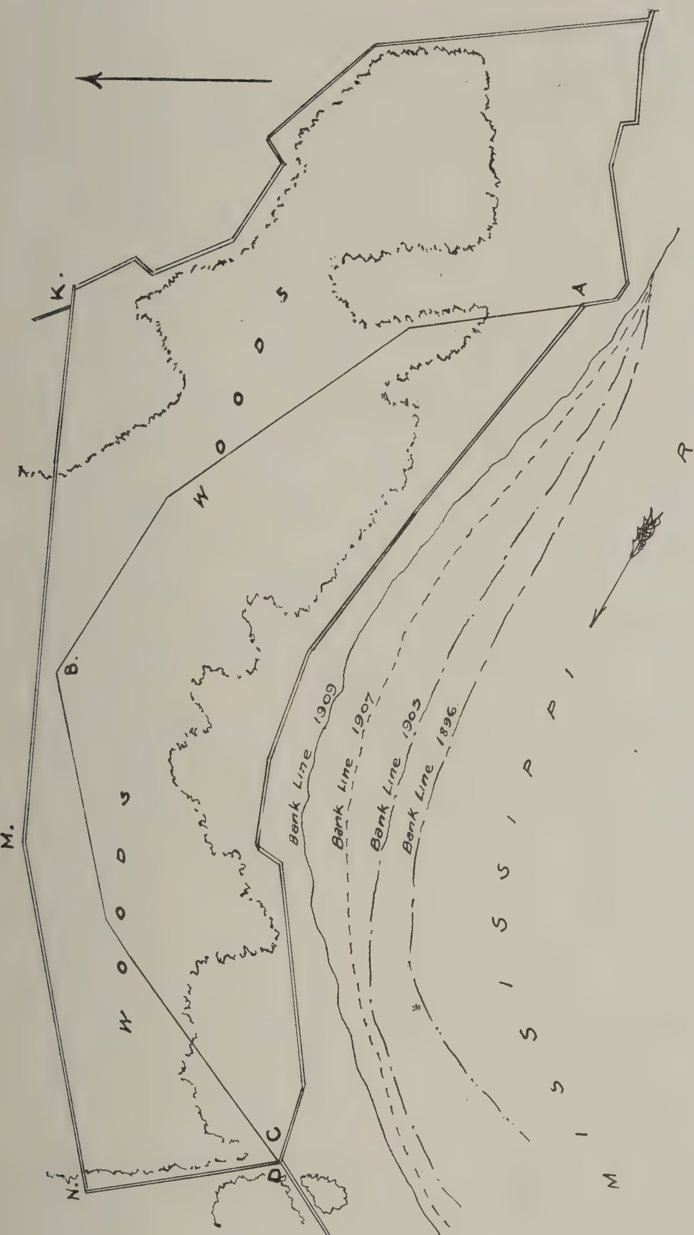


Fig. 3. Greens Levee. A, B, and C, line of 25-year life. K, M, N and O, line throwing out improved property, the value of which and the cost of construction on that line is less than construction of a levee on line A, B and C. Scale, 1—37,500.

Hence, the levees were built with an eye single to height and foundations were neglected. The better organization of the work caused more attention to be given to the proper design. The closing of the basins, destroying the reservoir system, gave increased flood heights. For a considerable period height was still the great problem, but new problems were presented. High levees would slough if built of the same form as low ones, necessitating the redesign of the sections. The grosser defects of foundations became evident and caused attention to be given to them. Gradually the levees have been brought to a height where that factor no longer governs. Steadily the levees are being brought to both a height and section where neither of these factors will cause anxiety. The work has progressed so far and the methods of high-water protection have been so improved by the introduction of floating levee machines that the district officer has little to fear from danger of overtopping or sloughing. As the levees proper have improved, the floods have been better confined, have reached greater heights, and have given an increasingly severe test of the foundations. Since 1900 there has been but one important levee failure (Torras) between Vicksburg and New Orleans from any cause except weakness of the foundation. The custom was formerly to ascribe these failures to gross defects in old construction, such as logs and roots left in the base, and, doubtless, some failures were due to such causes, but failures occurred where there was no evidence of gross defects in construction. The great floods of 1912, 1913, and 1916, exceeding all previous records for height, gave an exceptional opportunity to study the causes of failure.

Three crevasses occurred in the same manner and in three levees built on almost identical foundations; Hymelia, Lake St. John, and Buckridge. In each case the trouble appeared suddenly as a leak from the ground at some distance in the rear of the levee and worked rapidly back to and through the levee. For a short period each levee remained as an arch over the crevasse. Each levee was built along an old bed of the river. Previous to the breaks, the levees gave no trouble, but the whole country in the rear of them seeped freely. In the case of Hymelia there was doubt as to the construction being good. At Lake St. John there was strong presumptive evidence that there were no gross defects in the levees proper. The great gulches cut by both the crevasses destroyed any chance of studying the foundations as they existed formerly. At Buckridge the crevasse scoured out a pot-hole about 80 feet deep, but this hole extended only a short distance back of the break. Beyond that the ground was intact and could be studied.

Buckridge Levee was built by a distinguished officer of the Corps of Engineers, who later became its chief. The levee was enlarged by another officer who had much experience in levee construction. The assistant engineers and inspectors on the work are all men of the highest standing in their profession to-day. Nothing was lacking of skill in the design or of care in the construction. The

conventional 4-foot search-ditch revealed only the finest buckshot foundation. The construction has been exposed by the break and is such as might give satisfaction to any builder. The old levee is homogeneous and compact. In tearing down 200 feet of it to get earth for a new levee, not a sign of any vegetable matter or other defects was found. The levee is a tribute to the scrupulous care of its designers and builders. The material is buckshot. Four days before the break, the writer examined this levee and found no defects. At midnight of February 14 the levee showed no defects when the mounted patrol passed. Two hours and a half later the mounted patrol returned. The night sentinel reported a leak that had been running in the field, about 30 feet back of the levee, for about an hour. The patrol left his horse on the levee and went to examine the leak. A second leak broke out nearer the levee. The patrol went to examine it when the leak broke out like a geyser, so suddenly that the patrol was drenched. As he ran for the levee the crevasse occurred, leaving him on one side and his horse on the other.

Knowing the foundation to be bad, the writer caused a search-ditch of unusual depth to be cut along the line of the new levee built to close the break. This ditch showed everywhere, except directly opposite the break, a layer of buckshot from 6 to 8 feet thick. Directly opposite the break is a short stretch where the top layer is loam. Under the whole stretch is quicksand, into which a 3-yard clamshell bucket sinks 11 feet of its own weight. This quicksand flows to the bucket almost like a liquid. A slight head of water in the crevasse hole, 250 feet to 300 feet distant, causes typical sand-boil ebullitions in this material. Back of the old levee there existed a growth of willows and cottonwoods. From this information it would appear that the water under pressure found its way between the sand and the buckshot, possibly traveling part of the way along the line of a root after passing the levee. The pressure of the water probably arched the ground surface somewhat, giving a large channel through which water could flow when the surface was broken. So long as the crest was firm buckshot it resisted the pressure of the water, but when the loam was reached the water broke through. A flow once established, the surface layer was rapidly worn away.

This theory is supported by the action at L'Argent and Kempe levees during the high water of 1916. At L'Argent the conditions were the same as at Buckridge, except there were no trees near the levee and no streaks of loam in the surface layer. One sand-boil broke out in the levee and another farther downstream and about 60 feet from the levee. The first boil was promptly hooped and gave no more trouble, but the second was obdurate. The writer spent the next day at this levee and observed the action. During the night a second boil appeared between the first and the levee. These boils ran about 200 second-feet of water, which carried away the sand rapidly. The whole country was seeping freely. The

inner boil showed several distinct craters. Fig. 4 shows the general conditions and the method of sampling a boil. Samples taken of the output showed bits of buckshot with the sand (Fig. 5). On a line from the levee to the boils the ground had the appearance of being slightly raised. Whether this irregularity was natural or due to an arching of the crust can not be definitely stated. The writer inclines to the latter belief, because the boils were all in line, as if breaking through the crown of an arch. During the day a third and a fourth boil broke out on the same line, each closer to the levee than the one preceding. The writer saw the third boil appear. Without any warning, water burst out like a fountain and sand commenced to flow; eventually, the whole

Fig. 4.

Fig. 5.

Sample of Sand-boil at L'Argent, February, 1916. The sampler holds his hand in the flow from the boil, being careful not to agitate the surrounding sand. If the water is warmer to the hand than is the water in the river, there is little danger; but if the water be of approximately the same temperature, there is danger of a break. The flow from the boil deposits material in the sampler's hand. If this material be only sand, there is little danger; but if buckshot be present with the sand the boil is considered dangerous. Note how the whole country is covered with seepage coming out of the ground. Note, also, the poles with white rags attached. These marks are placed during the day time at every point of weakness on the levee, in order that the night guard may be sure to inspect them when he passes.

surface of the ground back of the levee was a mass of sand boils. Any weak spot, such as a streak of loam in the surface, would probably have caused a crevasse before the area was inclosed by a cofferdam.

The action at Kempe was very much the same. A number of sand boils appeared. The sand which flowed over-night from one great boil amounted to more than 1,000 cubic yards. Apparently this sand came from under the levee and left a cavity. The banquette broke and sank, as if into a great void, and sand temporarily ceased to flow from the boil.

The mere construction of a levee of full grade and section on a defective foundation does not give security and but little diminishes

Fig. 6. Sand-boil at Kempe, February, 1916. The foam shown in the illustration consists of sand so finely divided and loosely joined together that it will float on water. This foam is characteristic of sand-boils of the kind that are considered most dangerous.

the action which takes place. White Oak Levee is almost a continuation of the Buckridge Levee. Conditions here are somewhat different. The foundation is sand. Back of the levee is White Oak Lake. From the very start, this levee gave trouble. A banquette was built by local authorities during a yellow fever quarantine. Assistant Engineer W. E. Knobloch happened to be quarantined in the vicinity and saw the work done. The material used was muck from the lake bed. When the levee was enlarged to full grade and section, this banquette was disregarded and the

whole work was done to the front. The completed levee therefore had two 40-foot banquettes, giving a base 40 feet wider than standard. The work was completed just before the high water of 1916 and had practically no effect. Sand-boils, some quiet and some spouting, appeared in the lake. Part of the rejected banquette sloughed off and a good stream of water poured through. One hundred feet back of the levee another stream spouted a regular fountain.

The high water of 1916 showed that a levee of full grade and section *on a good foundation* will give no trouble and will afford complete protection against the floods that it is built to resist. The problem to-day is the foundation. A levee is nothing more nor less than an earthen reservoir wall. The same precautions that have to be taken with the foundations of reservoir walls of equal height will have to be taken with levee foundations. The conventional search-ditch can be relied upon in most situations, but around old lakes and other old beds of the river the engineer will do well to take careful borings if he expects to give his levee the required 25-year life.

COMMENTS *by* COL. C. McD. TOWNSEND, *Corps of Engineers; President Mississippi River Commission.*

The standard form of levee construction was adopted some thirty years ago, and resulted from practical experience. It was observed that with the soils generally found in the Mississippi delta, if the width of base of a levee exceeded ten times the head of water to which it was exposed during floods, there was little danger of a dangerous flow of sand through the ground on which the levee was established, while where the relation was reduced to less than eight to one, sand-boils became serious. For this reason the banquette was constructed behind the levee when its height exceeded 12 feet, and was given a width of from 20 to 40 feet according to the levee height.

As stated by the district officer, on account of lack of funds in the Lower Tensas levee district, the construction of the proper banquette has in many cases been omitted, and the levee given an excessive height without sufficient width of base, and serious troubles have been experienced with levees of that character during floods.

There has been, however, but one failure—that at Hymelia—in a levee that had been built to standard section, since its adoption some thirty years ago. At both Lake St. John and Buckridge, a banquette of proper dimensions had not been constructed.

The Commission, however, recognizes that in extremely porous soils, the standard section has not sufficient width of base to pre-

vent all sand movement, and three methods have been tried to correct such conditions:

First, by increasing the width of base, either by widening the banquette or adding a similar structure on the river side of the levee, as was done at Salem, La.;

Second, by driving a row of sheet piling to intercept the flow through the porous strata;

Third, by a system of sub-levees. The sub-levee is a secondary levee behind the first, which impounds water which percolates under it, thus reducing the head which is tending to displace the material. Occasionally, behind a high levee, there has been constructed a second sub-levee, dividing the head into three parts.

Diamond Drilling at Muscle Shoals, Tennessee River.

BY

Mr. W. S. Winn,
Assistant Engineer.

The Muscle Shoals section of the Tennessee River has been, from the beginning, a barrier between the navigable waters of the upper and lower reaches of the Tennessee River. The shoals section is about 37 miles long, extending from the head of Browns Island to the railroad bridge at Florence, Ala. Above the shoals there are approximately 350 miles and below them 256 miles of river on which boats plied for all save a few of the low water months, even before any improvements were made. Steamboats have rarely, and only under dire necessity, passed the shoals in the open river. There are of record not more than six such passages.

The importance of the Tennessee River, both in its size and as a probable developer of commerce throughout its rich and extensive basin, has placed it in the forefront of discussion as a waterway worthy of improvement for about one hundred years. Always prominent has been the subject of the treatment to be given the Muscle Shoals section. Two projects have been previously adopted and completed. The first, made by the State of Alabama with the assistance of the United States, died of neglect after it had been put into use.

The state retained control of the canal until 1875, when the

[This article has been published in substance in House Document 1262, 64th Congress, 1st session, as an appendix of reports on preliminary examination and survey of the Tennessee River between Browns Island and the Railroad Bridge below the City of Florence (Muscle Shoals Section) in connection with a proposed combined navigation and power improvement. Other appendices of this document relate to the survey of dam sites; flowage surveys and damages; backwater computations; lock, dam and power-house design; available power; etc., and are illustrated by numerous plates.

A brief description of the Muscle Shoals Section of the Tennessee River is printed in Professional Memoirs, pages 61 to 71, Vol. 8 (January-February, 1916.)—Ed.]

United States took it over and began the reconstruction. The old canal was rebuilt, using nine locks, however, to replace the original sixteen. This plan also embraced a canal 3½ miles long, with two locks, to surmount the Elk River section, and considerable open channel regulation between the two canals, above the Elk River section, and in Little Muscle Shoals.

For the first fifteen years after the present canal was opened all of the projects offered in connection with Muscle Shoals were for extending the canals, with the idea that the latter must be left intact.

It was not until the power development feature was injected into the discussion, about 1906, that a comprehensive plan for the improvement of the entire shoals section, adequate to present-day needs, was presented. Serious attention was first drawn to this by a report written by the late Senator John T. Morgan of Alabama, and published in 1906 as Senate Document No. 83, 59th Congress, 1st session. Almost coincident with the report, the Muscle Shoals Hydro-Electric Company was formed for the purpose of developing water power at Muscle Shoals by constructing dams across the stream. This scheme, involving as it did the obliteration of Muscle Shoals Canal, certainly required Government consent, and the power company went farther by asking for cooperation. The power company submitted tentative plans and a Board of Engineers was convened to pass on the proposition. The Board found that it had insufficient data upon which to base an estimate. The plan involved the construction of three power dams, each of about 40-foot head. Preliminary surveys were made to cover the proposed reservoirs and ten diamond drill holes were sunk along the axis of the proposed dams. The holes penetrated bed rock to a depth of 20 feet each. The report of this Board was published as Document No. 781, 60th Congress, 1st session.

No definite action was taken by Congress.

In 1910, Maj. Wm. W. Harts, Corps of Engineers, embodied a plan for the Muscle Shoals Section in a general project of the river from its source to its mouth. This plan contemplated the rebuilding of the Muscle Shoals Canal, widening and straightening it, reducing the number and adding to the lift of locks, and the improvement of the present open river reaches by the construction of dams.

Major Harts' report was published as House Document No. 360, 62nd Congress, 2nd session.

The project submitted was adopted by Congress except as to

the Muscle Shoals section, which was held in abeyance pending further studies of the power feature.

Under date of February 23, 1910, the Chief of Engineers convened a special Board of Engineers to consider and report on a combined improvement of the Tennessee River at Muscle Shoals, for navigation and water-power development. The Board had surveys made and plans prepared and invited bids for franchise for water-power development.

The Board's plan was for three power dams, the highest of which was to have a head of 67 feet.

The bid of the Muscle Shoals Hydro-Electric Company was declared the most satisfactory. The power company, however, submitted plans made by its own engineers, calling for only two power dams, the higher of which would have a head of 100 feet.

The Board's report was published as House Document No. 20, 63rd Congress, 2nd session.

It will be seen from the foregoing that many steps have been taken toward the final solution of the Muscle Shoals problem, and each step taken to keep pace with the progress of the times has demanded additional data commensurate with the plans in mind. Beginning with a simple canal and locks of 5-foot lift, the steps have brought us to-day to the ambitious plan embracing a dam about 95 feet high, 4,100 feet long, and surmounted by a flight of three locks; and another dam having 40-foot head, 6,200 feet long and having a single lift lock.

When it is noted that structures of such magnitude are to be founded in a river having a maximum flow of 500,000 second-feet, it will be granted that the most careful sub-surface investigations were warranted.

In its report (House Document No. 20), the special Board recommended an appropriation of $150,000 to provide for the completion of detailed surveys, foundation borings, and preparation of plans so that there need be no unnecessary delay in prosecution of the work whenever it is authorized.

Congress, in the Rivers and Harbors Act of March 4, 1915, provided for the continuation of investigations at Muscle Shoals.

CONTRACT AND SPECIFICATIONS.

In anticipation of an investigation of the foundations for the dams being ordered by Congress, an extensive system of diamond drilling was advertised for June 17, 1914, the specifications of which were as follows:

Description of the Site and Work.

Par. 19. *Location.* The site of Dam No. 2 is at Florence, Ala. It is expected that satisfactory foundation conditions will be found at the location indicated by the lines "A" and "B" on the map referred to in paragraph 23. In the event that holes at this location prove unsatisfactory, the right is reserved to shift the location about three-fourths of a mile upstream to approximately the position indicated by the lines "C" and "D" on the abovementioned map. . . .

Par. 21. *Range of water surface at dam sites.* The ordinary range of water surface in the river at the site of Dam No. 2 is about 25 feet and at site of Dam No. 3 is about 11 feet. High water may occur at any time of the year, but is ordinarily of lesser height during the months of July, August, September, October and November, this being the usual season of low water.

Par. 22. *Visiting dam sites.* Prospective bidders are expected to visit the sites of the work, to examine the river hydrographs, to acquaint themselves with the conditions connected with materials and transportation, and to make their own estimates of the cost and the difficulties as to labor in the execution of the contract. Before visiting the sites, prospective bidders should communicate with this office so that information can be given which will enable them to identify the sites.

Par. 23. *Drawings.* The combined drawings and maps marked "Tennessee River, Muscle Shoals Section, Alabama. Location of Diamond Drill Holes," in two sheets, form part of these specifications. Blueprints of these sheets will be furnished to prospective bidders upon application.

Par. 24. *Location of holes.* Two sites are to examined—for Dam No. 2 and for Dam No. 3—and for each site the proposed layout of holes is shown on the drawings. On sheet No. 1 the lines "A" and "B" are at the selected site for the structures, but if the borings indicate that the foundation is unsatisfactory at this site, it is proposed to shift the location to the site marked with the lines of holes "C" and "D." The United States reserves the right to make further changes in locations should the borings at any time indicate the necessity of abandoning the site being examined, but it is believed that there is little likelihood of any considerable change at site for Dam No. 3, nor for any examination upstream from line "C" on Sheet 1, or downstream from line "A."

Par. 25. *Distances between holes.* The distances between lines of holes and the spacing of the holes in each line are shown on the drawings. The opposite holes of the two lines are designated herein as "Pair of holes." Changes in distances between lines and in spacing of holes shall be made, if so directed by the contracting officer, under the limitation as to quantities given in paragraph 37.

Par. 26. *Preliminary exploration.* Prior to making the complete set of borings for each site, there shall first be driven a preliminary line of holes, consisting of every fourth hole on the upstream line for each site, and such other holes as may be directed by the contracting officer. Should these preliminary holes indicate the necessity for a change in the location, a new site will be selected and at the new location a similar preliminary line of holes will be driven, but in case the preliminary holes give satisfactory indications, the complete set of holes will be put down and tested.

Par. 27. *Depths of holes.* Holes will be bored to approximate bottom eleva-

tion of 347 and 367 for site No. 2, and bottom elevation of 460 for site No. 3. For site No. 2 the alternate pair of holes shall be driven to the elevations 347 and 367, and those along the axis of the lock wall to elevation 367. The United States reserves the right to direct an increase in depth for any hole by 50 feet.

Par. 28. *Method of drilling.* It is expected that all holes in rock will be driven with the diamond drill and that cores will be preserved, but it is desired that bidders offer an alternative bid, as provided on the bidding sheet, providing for the driving of the downstream holes of each pair by the use of a percussion drill. The United States reserves the right to accept either of the alternative bids.

Par. 29. *Holes and cores.* Bidders will state the size of cores which it is proposed to bore. It is desired that the core be between 1⅛ and 2 inches in diameter. The size of the percussion drill hole which it is proposed to drive should also be stated.

Par. 30. *Log of holes* The drill operators shall keep a complete record of each hole, and shall preserve the core wherever practicable. The core shall be preserved in suitable core boxes, in proper relative position. Each linear foot of core shall be represented by the same length in the core box, and where core has not been recovered the corresponding space in the box shall be represented by a wooden separator of required length, which shall have inscribed thereon as full information as practicable of the character of the material encountered in that part of the hole represented by the separator. Samples of the washings from parts of holes from which core is not recovered shall be preserved in bottles, so labeled as to permit ready reference to the corresponding wooden separator. Samples of material from the overburden holes and from holes driven by the percussion drill shall be preserved in bottles when directed by the contracting officer, but the length of the overburden hole will not be represented in the core box.

Par. 31. *Containers for cores.* All boxes for cores and bottles for samples of materials will be furnished free of charge by the United States, as will also the material required for the wooden separators, which will be furnished in stock lengths, dressed to proper cross-section.

Par. 32. *Classification of holes.* Holes will be classified as "rock holes" and "overburden holes." All holes or parts of holes which are driven through solid rock by the use of diamond or percussion drill will be classed as "rock holes," and will be paid for under contract price per linear foot for diamond drilling or for percussion drilling, depending upon the methods used. All holes or parts of holes driven through silt, sand, loam, clay, gravel or hard-pan will be classed as "overburden holes," and will be paid for by the linear foot at the contract price for overburden drilling.

Par. 33. *Occurrence of materials.* Almost everywhere in the bed of the stream there is little or no material overlying the rock, and where such material is encountered it is composed of silt, sand or gravel. On Pattons Island the overburden is composed chiefly of silt with some sand and gravel. On the banks, so far as known, the overburden is composed of loam, clay, sand and gravel, and in places of partially disintegrated rock. At places on the banks ledges of rock may be found between successive layers of softer materials, and where such ledges are encountered the contractor may use either the

diamond or percussion drill, or may drive the casing through such ledges by any other method which is suitable.

Par. 34. *Character of material.* Two diamond drill holes were put down in 1908 approximately on line "C," and four holes along the axis of the proposed Dam No. 3, each of the holes penetrating about 20 feet into bed rock. The log of the holes designates the materials penetrated as "flint," "limestone," "limestone and flint," and "brown rock," . . .

Par. 35. Several wash-bored holes were driven to bed rock approximately in prolongation of the axis of Dam No. 2, and from the record of such holes was prepared the typical section shown on sheet 1 of the drawings. All information on file in the district office as to quality of rock and other materials may be examined by prospective bidders. It must be remembered that the sections shown on the two drawings are not to be taken as representing other than assumed conditions, the examination to be carried on under the proposed contract being for the purpose of obtaining knowledge of exact conditions.

Par. 36. *Pressure tests.* Every pair of holes at site No. 2 shall be tested hydraulically under a pressure of 100 pounds per square inch, and at site No. 3 under 50 pounds per square inch, the pressure being applied to the upper hole, unless otherwise directed by the contracting officer. When 100 pounds pressure is reached, as indicated by the attached gage, the power shall be cut off, the time noted, and the loss in pounds on the gage in 60 seconds shall be noted and recorded. If the loss in pounds on the gage in 60 seconds is more than 20 pounds, or if the gage races between successive strokes of the pump, it will be taken as evidence of a leak, and a detailed test of the hole will then be required. This test will be made by successively applying the above test to each 5-foot length of hole, beginning at the top, until the leak is located in elevation. When an important leak is located, the other hole of the pair will likewise be tested in detail. The testing of the holes will be paid for at the contract price per hole, and the detail testing at the contract price per 5-foot depth of actually retested portion of the leaky holes. Bidders shall submit with their bids a complete description of the machines and methods proposed to be used in the testing of the holes, as a whole and in detail.

Par. 37. *Quantities.* The estimated number of holes to be drilled is 255, with an estimated aggregate length of 9,810 linear feet of rock-hole and 2,330 linear feet of overburden hole, but the United States reserves the right to increase the aggregate length of both the rock hole and the overburden hole by an amount not exceeding 100 per cent, or to decrease the aggregate lengths by an amount not exceeding 10 per cent. The quantity of detailed testing is indeterminate, but for the purpose of comparing bids it will be assumed that there are to be 200 5-foot lengths of re-tested hole, but it must be understood that the United States may require a larger or smaller amount of detailed testing, depending on the conditions discovered.

Par. 38. If the aggregate lengths of hole are increased the time allowed in paragraph 15 for the completion of the contract will be increased in like proportions; that is, if the aggregate amount of drilling is increased by a certain percentage, the total number of calendar days will be increased by the same percentage.

In response to the advertisement, the following bids were received:

Abstract of Bids for Diamond Drilling at Muscle Shoals.

Name and address of bidder.	Rock hole diamond drilling 9,810 linear feet. *Per linear foot.*	Rock hole percussion drilling 9,810 linear feet alternative *Per linear foot.*	Overburden hole 2,330 linear feet. *Per linear foot.*	Testing holes. *Per hole.*	Detailed retesting of leaky holes, 200 5-ft. lengths. *Per 5-foot depth of portion of hole actually retested.*	Total cost.
The J. A. Brennan Drilling Co. 30 Carsin Street, Pittsburg, Pa.	$3.75	$2.50	$2.00	$4.00	$3.00	$42,507.50
Giles & Clark 30 Church Street, New York, N. Y.	6.50	7.00	2.00	3.00	2.00	69,170.00
H. B. Ameling Prospecting Co. Liggett Building, St. Louis, Mo.	9.90	------	2.50	2.00	1.00	103,374.00
The T. A. Scott Co., Inc. New London, Conn.	8.93	------	5.75	20.00	10.00	105,300.80
Sprague & Henwood, Inc. Scranton, Pa.	3.25	------	3.25	5.00	2.00	40,430.00
Sullivan Machine Company 122 So. Michigan Ave., Chicago, Ill.	9.00	------	9.00	5.00	2.50	110,335.00

The bid of Sprague & Henwood was the lowest received and was therefore recommended for acceptance. The funds not having been appropriated by the Rivers and Harbors Act of 1914, nothing further was done than to notify Sprague & Henwood, Inc., that their offer was satisfactory.

The Rivers and Harbors bill of 1915 having been passed, an allotment of funds for the work was made on April 2, 1915. The successful bidders having indicated their desire to accept a contract upon the basis of the old offer, the contract was accordingly entered into. The contractor was notified of the approval of the contract April 17, 1915. On April 19 the first hole was started. Drilling at dam site No. 3 was finished August 14 and at dam site No. 2 September 4.

CONTRACTORS EQUIPMENT.

Under the terms of their offer the contractors would have been required to put on twelve outfits; instead, thirteen outfits were shipped to the job. While all of the outfits were not worked at any one time, it advanced the progress of the drilling to have extra machines on hand to replace those out of commission for repairs. Three of the drills were driven by steam and ten by gasoline. The steam outfits were used on the banks of the river, where they were accessible to coal, and gasoline was used for the drills in the stream and on islands. All of the machines were of standard size for taking 1⅛-inch core. They were manufactured in the contractor's own shops.

For drilling holes in the stream bed the gasoline drills were mounted on barges 2′ 4″ × 12′ 0″ × 20′ 4″. A sketch of one of these barges is given (Fig. 1), and is included for the purpose of showing with what simple, inexpensive floating plant the contractor was willing to undertake such a large job in a river of the size of the Tennessee, having swift currents and rock bottom.

The barges would have no salvage value at the end of the job and were built as cheap as possible, to stand the few months service for which they were designed. They were built by the drill operators, none of whom were ship carpenters, and their kit of tools consisted of saws, hatchets and crude calking tools. A liberal coat of pitch served to render the calking efficient. The contractor stated that they cost about $100 each. Built by experienced carpenters, the cost should not have exceeded $70 each.

The weakest part seemed to be in the spud attachment to the

hull, which consisted of two stirrups of 5/8-inch round iron to each spud. The spuds were raised by two men lifting with their hands. The barge was spudded up with the aid of a block and tackle, one block being attached to the top of the spud and the other to an eye-bolt in the deck. They were held in this position by the tackle and steadied by driving wedges between the spud and the barge gunwale.

The whole rig looked rather flimsy and failure was freely pre-

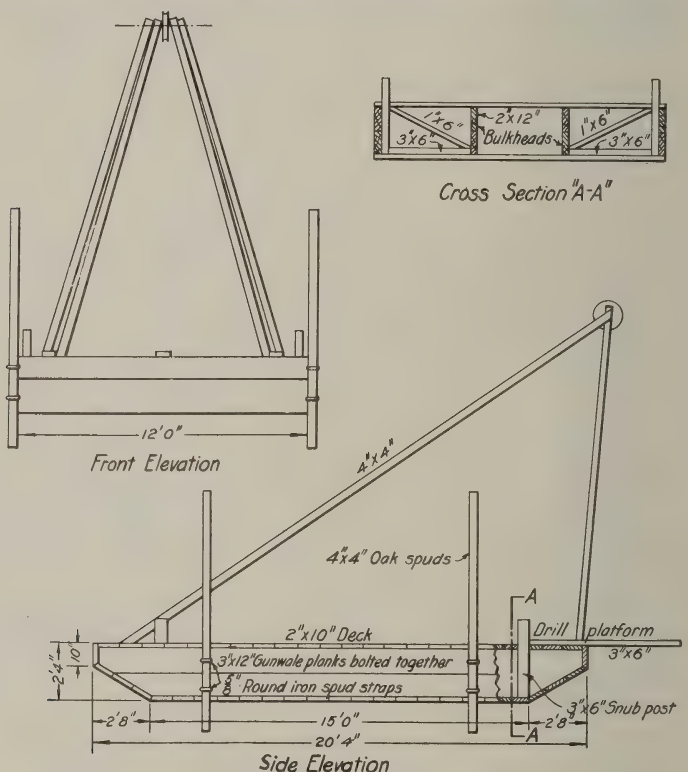


Fig. 1. Muscle Shoals Sub-surface Investigations. Barge used in diamond drilling.

dicted, but the barges all came through the job in apparently good condition. Several of them had their forward ends shot out in blasting for casing holes, but they were so light they were easily pulled up on a rock and repaired. Their lightness was of advantage also in moving in the shallow water. They were often dragged over rocks having less depth of water over them than the draft of the barges.

A sketch of the pressure testing apparatus used is shown in Fig. 2.

Water to carry away the débris from the cutting edge of the drill in holes on land, was supplied by a small steam pump located on the river bank. In the holes drilled from barges a hand deck-pump, worked by one man, supplied the water.

The rest of the contractor's equipment was the usual assortment

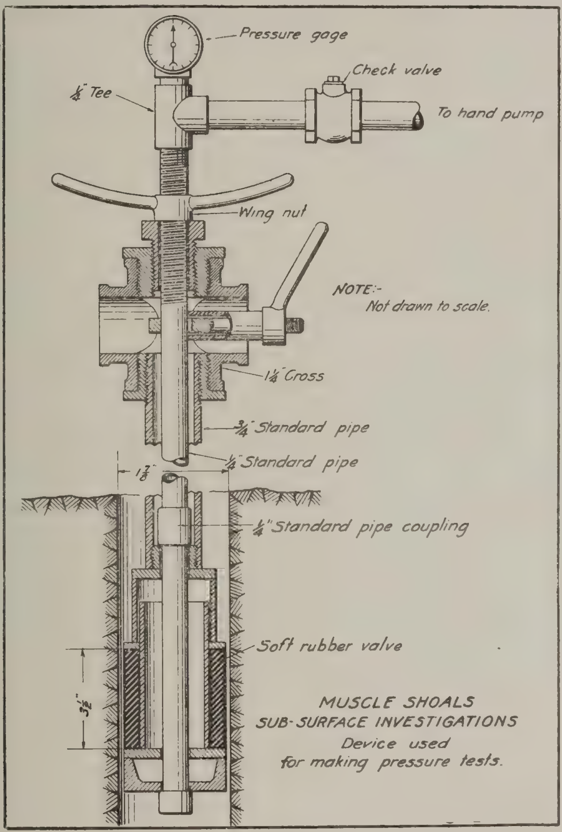


Fig. 2.

for outfits of the size used. A small rough board shack was built at each site for use as a diamond setting shop and for storing extra parts, etc.

LOCATION OF SITES.

The location of Dams Nos. 2 and 3, with relation to one another and to the cities of Florence and Sheffield, is shown on the plate opposite page 60 of Volume 8, PROFESSIONAL MEMOIRS (No. 37).

Plan of the layout of the holes for the two dam sites, on drawings 2-DD-1 and 3-DD-1.[1] Sections along lines of drill holes on drawings 2-DD-2, 3 and 4, and 3-DD-2 and 3.[1]

Before drilling began a shift in the location of Dam No. 2, of about 5,800 feet upstream, was approved. One of the chief reasons for the change in location was to take advantage of the rock bluff at the upper location, upon which to found the locks. The upstream lock will be practically on top of the bluff, the middle lock steps down to a lower bench, and the downstream lock comes down to rock at the river bed elevation. At the lower location there is no rock bluff on the right bank and all of the three locks would have their foundations practically at river bed elevation.

METHOD OF PROCEDURE.

The specifications provided that a series of exploration holes, consisting of every fourth hole on the upstream line for each site, should first be driven. It was thought that this would show general conditions and develop unfavorable conditions, if any existed, that would necessitate a change of location, as provided for in paragraph 24 of the specifications. After this plan had been carried far enough to determine that no change of location would have to be made, the contractor was allowed to put down the holes in the order that best suited the arrangement of the plant. The machines were well distributed over the sites.

As the work progressed and results were so uniform, some of the holes on the downstream line at each site were omitted where the upstream hole of the pair had proven satisfactory. Some of the pressure tests were also omitted.

At dam site No. 2 five holes, about equally spaced across the stream, were driven to bottom elevation of 297, or 50 feet lower than the deeper holes on the regular layout. This developed the strata for approximately 100 feet beneath the river bed. At dam site No. 3 three such holes were driven to twice the ordinary depth.

LOCATION OF HOLES.

Each line of holes was first marked on each bank with a stout hub. The holes were then approximately spaced along the line with a pliant wire cable. When a drill was set up for a hole it was

[1]Printed in House Document 1262, 64th Congress, 1st session, as Plates 8 to 13, respectively.

accurately located by triangulation from carefully measured bases on the islands and main shores.

NOTES AND CHARTS.

Field notes were recorded on cross-section sheets, 16 by 21 inches. The sheets were attached to light sketching boards with thumb tacks, and were carried to the field in waterproof bags. The notes in the field were recorded with pencil or fountain pen. When a hole was finished, the inspector who had charge of the hole transcribed his notes to a fresh sheet with a typewriter. This sheet is intended for a permanent record in the district engineer's office, hence all data noted on these field sheets were transcribed on the office sheets. The transcribed sheet was then sent to the Florence office, where a tracing was made of the diagram end of the sheet, and on it was placed everything of general interest. On the tracing the rate of progress of the drill is shown graphically. This eliminates a profusion of notes as to time of beginning, periods of delay, time required, etc., but gives all the information needed for a study of the chart. A sample of the transcribed copy is shown in Plate I. The diagram of each hole is given twice, once divided into solid black and solid white spaces, the white spaces representing the amount of core which was not recovered, and the black spaces the amount recovered for each pull. The other diagram for the hole shows character of rock, the conventional signs indicating the different materials encountered. To the right of the first diagram, there is plotted an irregular curve which gives the number of minutes per foot of rock drilled. To the left of the second diagram is shown the record of pressure testing. As an example, P-100-15-60″ means that the pressure was brought up to 100 pounds, and after the pump had been stopped for sixty seconds the pressure had fallen to 15 pounds.

PRESERVATION OF CORES.

All of the cores were preserved intact and are now stored in a warehouse at Lock 6, Muscle Shoals Canal, where they can be inspected at any time. It is proposed to preserve them until the construction of the dam is well along toward completion.

For convenience in handling the boxes, they were made 3½ feet long, inside measurement. Those for Dam No. 2 contained fifteen core slots, and for Dam No. 3 ten core slots. One box, therefore, contained an ordinary core; for the deeper holes, two or

more boxes were used. The full depth of the hole was represented by an equal length of core slot in its box. Where the core recovered was insufficient to fill its corresponding space in the core box, a wooden filler of the same diameter as the core was inserted. The wooden fillers, in this way, show the lack of core recovery for each pull. Elevations of bottom of each core pull were recorded in india ink on the adjacent partitions between core slots.

Since one of the chief reasons for preserving the core is that they may be inspected in the future, ready identification of a core and ease of access to it are desirable. To attain this, rough cases for receiving the core boxes were built. The core boxes were

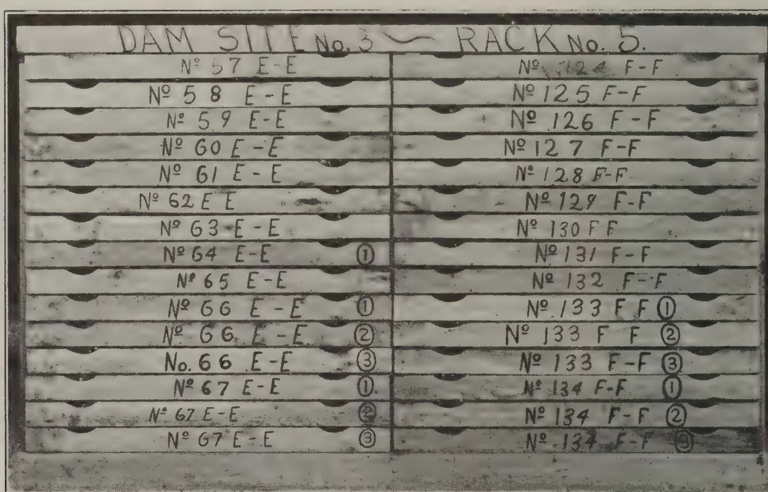


Fig. 3. Type of rack used for storing cores from diamond drill borings.

made like shallow drawers; as soon as one was filled it was marked and slipped into its proper place in a case. Each case has four sets of drawers, two sets pulling out on opposite faces. Each case contains sixty drawers, and five cases were required. Fig. 3 shows a filled case, which has the appearance of a chest of drawers. Fig. 4 shows filled core boxes. Attention is invited to the construction of the core boxes. Instead of the usual plan of giving the box a flat bottom and separating the core slots with thin partition slats, the body of this box was made of 1⅞-inch boards, and the slots ploughed out with a wood-working machine. In this way a stiff box was secured and at a small cost. They were made in the shops at Muscle Shoals Canal, of cheap lumber, by low-priced men.

PRESSURE TESTS.

Fig. 2 is a sketch of the device the contractor used for applying water pressure tests to the drill holes. The method followed was first to apply the pressure to the entire hole, the expandable washer being placed as near the top of the hole as practicable. If this test failed to meet the requirements (paragraph 36 of the specifications) the tester was dropped 5 feet lower in the hole, and pressure again applied, and so on to the bottom of the hole, or until the required pressure was secured. Tests of some of the holes in the downstream lines were omitted where the correspond-

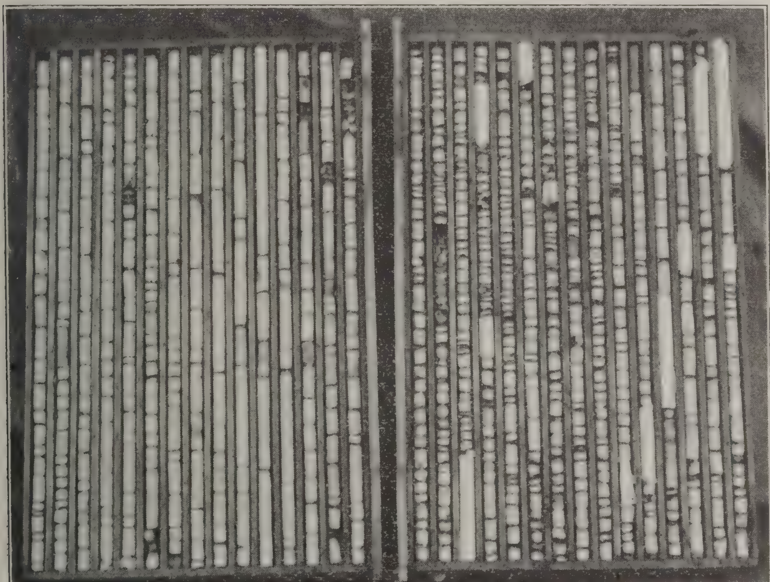


Fig. 4. Typical set of drawers, showing cores obtained from diamond drill borings.

ing hole on the upstream line had proven satisfactory in both quality of core and pressure test. The method was somewhat varied in the deep holes on the left bank of Dam No. 2.

The first of these holes drilled was No. 48. In this hole a cavity was found at about river bed elevation. Naturally, no pressure test held above this cavity. It seemed desirable to know whether the strata above that elevation were watertight, so, in the remaining holes on the left bank, the procedure was to test in 20-foot sections as the drilling advanced. This disclosed the fact that the seams between strata are remarkably tight. It is true that holes Nos.

46 and 96 showed low pressure tests, but this was on account of their nearness to the face of the bluff.

Some of the pressure tests seem to be slightly erratic. For instance, in hole No. 3 on the right bank, the pressure at elevation 420 ran down from 100 to 25 pounds in sixty seconds. For the next five detail tests it ran down to 15 pounds, but for the next 5 feet below it held up to 95 pounds at the end of sixty seconds. There is no explanation to offer for this, except that the rubber washer may not have been absolutely tight in some of the tests and that the result was too small indicated pressures. The dis-

Fig. 5. View of abutment on right bank (lock side of river) of proposed Dam No. 3, in connection with Plan of Improvement for Navigation and Development of Water Power in the Muscle Shoals Section of Tennessee River. October 22, 1913. The white line is at crest elevation (540) and face line of dam, just below Lock 2 in Muscle Shoals Canal. Muscle Shoals Canal and railroad shown in foreground. This location is about 1,000 feet below present Lock No. 2 in canal.

crepancy is small, and attention is only called to it as one of the very few inconsistencies in the work.

Considering the severity of the tests, the results are considered rather remarkable. The water was pumped into the holes through a ¼-inch pipe. That by this means, and using a small steam pump, the pressure was brought to 100 pounds without trouble,

was evidence that no leaks of consequence existed in the strata, and that in most instances some pressure was retained at the expiration of sixty seconds, shows that the foundations are practically impervious to water. A few drops of water leaking from a hole would have brought the pressure down immediately; as, in testing cast iron pipe, the mere sweating of a pipe through a porous part of it will rapidly reduce the pressure. In the deep holes in the river bed, it is believed that the shale underlying the harder measures, simply absorbed the water fast enough to reduce gage pressure. In every instance, the shallower holes adjacent to the

Fig. 6. Power house site (left bank) of High Dam No. 2.

deep holes give very satisfactory tests close to the river bed surface.

The maximum head on Dam No. 2 will be about 95 feet. A column of water 95 feet high exerts a pressure of 41.2 pounds per square inch. The pressure therefore applied to the drill holes was about 2½ times that due to head above the dam. The same relation existed between applied pressure and pressure due to the proposed height of dam at dam site No. 3.

Great care was exercised to get correct results. The gages were frequently tested with a standardized gage at Lock No. 6, and all parts of the apparatus were watched during the tests.

CORE RECOVERY.

It is believed that the percentage of core recovery compares favorably with the results obtained on similar work elsewhere. The recovery could have been increased both by drawing the core oftener and by taking a larger core, say 2 inches in diameter. The former was found to be true by experiment, and, judging by reports available on drilling operations at other places, it is the common experience that the oftener the core is pulled the greater the recovery. It was found that by pulling the core twice as often the core loss was cut almost in two. The core lost was simply ground up and washed out of the top of the casing. The grinding effect was shown in the cone-shaped ends of some of the pieces of core. Vibration of the core barrel and drill rods broke the core into short lengths, which became more or less jammed in the barrel, causing breakage into still smaller pieces. A larger drill would have had less vibration in rods and core barrel, and the larger core would not have broken so easily. Still, for the purpose in view the results are considered very satisfactory. Below is given a table showing core recovery at each dam site.

	Dam No. 2.	Dam No. 3.
Number of holes	90	133
Total linear feet in rock	5,194	4,947
Aggregate length of cores recovered	4,591	4,003
Percentage of core recovery:		
Maximum	99.0	96.4
Minimum	73.0	52.4
Average	88.4	80.7
Seams:		
Numbers	100	58
Aggregate depth (feet)	22.94	18.33
Cavities:		
Number	12	3
Aggregate depth (feet)	24.85	25.86

CONTRACTOR'S FORCE AND EQUIPMENT.

No account was kept of the contractor's force until a drill was on the ground ready to be set up at a hole location. Following is a table showing force employed, man-days worked and rate of progress:

	Dam No. 2.	Dam No. 3.
Total time of diamond setters (man-days)	195	135
Total time of drill runners (man-days)	688	441
Total time of laborers and helpers (man-days)	1,462	1,077
Total linear feet drilled in rock	5,194	4,947
Total linear feet drilled in overburden	1,128	400
Aggregate depth of holes (feet)	6,322	5,347
Machine days worked	676	408
Average depth drilled per machine day	9.4	13.1
Total time (in 8-hour days) actual drilling	495	261
Average per day, actual drilling time (feet)	12.8	20.5
Time lost moving drills, etc. (days)	181	147

The aggregate length of hole at both sites was 11,669 feet.

The average depth drilled per machine per day was 10.76 linear feet. Since the price per linear foot was exactly the same ($3.25 per foot), and the rate of progress nearly so, for rock and overburden, both are combined in arriving at feet drilled per day. The maximum speed for short runs was 5.93 and 11.96 feet per hour, and the minimum 0.14 and 0.61 of a foot per hour at Dams Nos. 2 and 3, respectively.

DIAMOND LOSS.

An interesting feature of diamond drilling, and one of the principal elements in the cost, is the diamond loss; but drilling contractors jealously guard such information as a trade secret. It is regretted that a statement of diamond loss can not be given in this article. It can be stated, however, that the diamond loss was less than the writer had expected. This was due in part to the skill of the setters and drill runners, but in a great measure to a practice, common to diamond drilling contractors, to which the contractors resorted. No new stones were used; instead, old stones, previously used in soft measures and which had had their sharp edges worn off, were brought to the job. The loss from wear was therefore a minimum. Several stones were crushed, but the chips were recovered. Only two stones were reported as being lost outright.

WHAT WAS FOUND.

Seams.

A soft joint between two successive strata of harder materials was classed as a seam. Its presence could be detected only by a

speeding up of the drill. In some instances there may have been a slight void in the seam, but if so it is not believed that the empty cracks extended very far from the drill holes. An examination of the blasted faces of the bluffs along Muscle Shoals Canal and the pressure tests in the holes bear out this view. It was difficult at all times to class a section of a hole as a seam. It is doubtless true that many of the so-called "seams" were simply softer rock between two flint layers in the same strata. When drilling first began, one of the drill operators of many years' experience, when a drill speeded up a little, remarked that it was passing through a seam. The core recovery for that pull was perfect and, at the elevation where the seam was expected, the core showed softer rock between flint streaks. The average thickness of seams was at dam site No. 3, 0.31 of a foot and dam site No. 2, 0.26 of a foot.

Cavities.

A hollow place in the rock formation, either void or filled with sand, silt or other unstratified substance, which offered no resistance to the speed of the drill, was classed as a cavity. Twelve cavities are reported at Dam No. 2, all except three of which are on the left bank and above river bed elevation. Six of these, aggregating 14.75 feet in depth, are in one hole 200 feet below the line of the dam. The three cavities in holes in the river are near the surface and likely are vertical seams. In any event, the cut-off section of the wall will take care of them.

The cavity in hole No. 48, evidently, is not very extensive. A thin seam at about the same elevation occurred in hole No. 47, but in the next hole toward the river, No. 46, no trace of a seam was found. In hole No. 49, 100 feet inland from hole No. 48, no seam appeared and the pressure test, at and below the elevation of the cavity in No. 48, showed no loss of pressure, showing that the cavity had "pinched out" on that side.

At dam site No. 3, all but one of the cavities are on the left bank. Hole No. 134 contains two of them, aggregating 21.52 feet in depth. Indications are that the deeper of the two is a vertical seam.

Gas.

One unexpected phenomenon occurred. Gas was struck in two holes, Nos. 4 and 34, at Dam No. 2. In hole No. 4 the back pressure registered 25 pounds. The jet ignited, shot up around the drill and continued to burn for twenty-four hours. The flow then

DATE	CORE RECOVER
July 19th	
9 45	
July 20th	
11 20	
July 21st	
July 22nd	
8 00	
10 00	4 28
11 00	93
11 50	18
1 45	1 84
3 45	3 34
July 23rd	
8 00	
11 00	3 13
1 45	2 89
2 45	65
3 55	97
July 24th	
8 00	
10 15	2 72
11 30	65
3 30	5 80
July 26th	
8 00	
10 35	3 26
12 15	1 77
3 35	4 79
3 50	1 08
July 27th	
8 00	
10 50	3 07
1 15	6 75
3 50	3 47
July 28th	
8 00	
10 35	6 31
1 25	5 98
3 45	7 62
July 29th	
8 00	
10 05	8 08
12 00	3 70
	ELE
July 29th	
1 00	4 5
	4 50
	4 45
	4 40
	4 3
	4 30
	4 25
	4 20
July 30th	
8 00	4 15
	4 10
	4 05
	4 00

PROGRESS HOLE Nº 3.

DATE	CORE RECOVERED	FEET DRILLED	ELEVATION BOT. HOLE	NOTES.
July 19th				
9.45				Began moving to hole.
July 20th				
11.20				Began driving casing. Elev. ground 494.00
July 21st.				Driving casing. Overburden clay, chert, flint broken L.s. El. rock 457.80.
July 22nd.				
8.00				Began drilling.
10.00	4.25	4.25	453.55	Delayed 30 mins. on bit.
11.00	.93	.93	452.62	Dull bit.
11.30	.18	.18	452.44	
1.45	1.84	1.93	450.51	Chopped .09' core
3.45	3.54	3.54	446.97	Total 10.83' Worked 7½ Hrs.
July 23rd.				
8.00				Began Work
11.00	3.13	3.21	443.76	
1.45	2.89	3.08	440.68	Chopped .16' core.
2.45	.65	.67	440.01	Changed bits
3.55	.37	.42	439.59	Total 7.38' Worked 8 Hrs
July 24th.				
8.00				Began work.
10.15	3.72	3.72	435.87	
11.30	.65	.77	435.10	
3.30	5.80	6.35	428.75	Total 10.84' Worked 8 hours.
July 26th.				
8.00				Began work. Chopped .16' core.
10.35	3.35	4.43	424.32	Core badly broken and ground away
12.15	1.77	2.14	422.18	Core badly broken.
3.35	4.79	5.09	417.09	
3.50	1.09	1.22	415.87	Total. 12.88' Worked 8 hours.
July 27th.				
8.00				Began work. Reamed 7.50'.
10.50	3.07	3.45	412.42	
1.15	6.75	7.10	405.32	
3.50	3.47	3.55	401.77	Total 14.10' Worked 8 hours.
July 28th.				
8.00				Began work. Chopped .08' core.
10.35	6.31	6.55	395.22	Delayed 30' mins for repairs.
1.25	5.58	6.91	388.31	Core crushed and ground away.
3.45	7.62	8.17	380.14	Total 21.63' Worked 7½ Hrs.
July 29th.				Began work
8.00				
10.05	8.08	8.08	372.06	
12.00	3.70	5.06	367.00	Total 13.14' Worked 6 Hrs.

PRESSURE TESTS

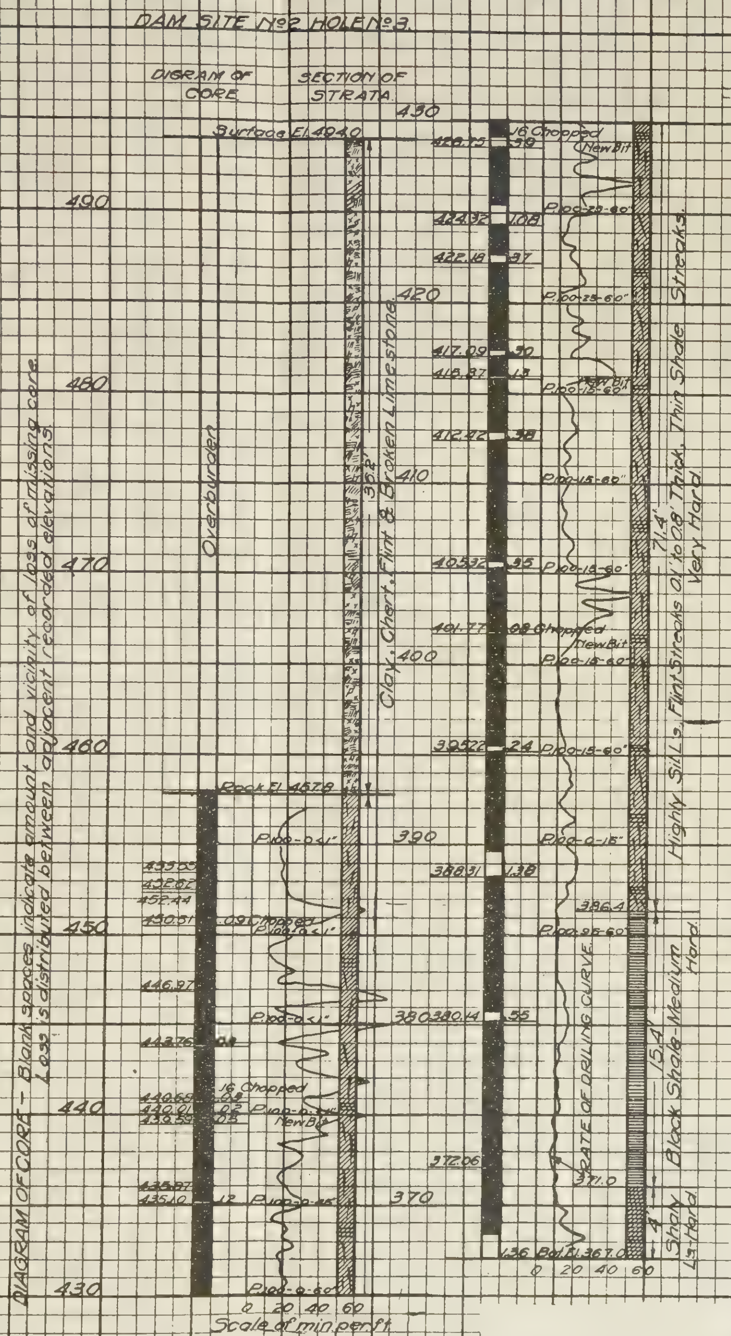
	ELEVATIONS	PRESSURE IN LBS. PER SQ. INCH.	TIME IN SECONDS.
July 29th.			
1.00	455.00	100 to 0	1-
	450.00	100 to 0	1-
	445.00	100 to 0	1-
	440.00	100 to 0	1-
	435.00	100 to 0	45
	430.00	100 to 0	60
	425.00	100 to 25	60
	420.00	100 to 25	60
July 30th.			
8.00	415.00	100 to 15	60
	410.00	100 to 15	60
	405.00	100 to 15	60
	400.00	100 to 15	60

PRESSURE TESTS Cont'd.

395.00	100 to 15	60
390.00	100 to 0	18'
385.00	100 to 95	60

Gage Nº 330829A Tested at Lock #6. July 19th.

Last four tests made with gage Nº 330841A Tested June 10th.



GENERAL NOTES.

Inspector: Dwight C. Trevarthen.
Assisted by L.C. Duckett

Contractor: Sprague & Henwood
Drill Runner: Geo. Ross.
Helper: 1
Firemen: 2
Diamond Setter: Jas. Ross.

Drill outfit Nº 208.

Overburden	36.20'
Rock	90.80
Total	127.00
Primary test	1
Detail tests	14

Location: 2+00 on line G-G.

Core placed in box and sent to lock #6.

Abbreviations:

L.S.	Limestone.
Sl.	Slate.
Fl.	Flint.
Calc.	Calcareous
Sdy.	Sandy.
Sa.	Sand.
Sil.	Siliceous.
Sh.	Shale.
P.	Pressure in Lbs. per sq. inch.

Strata classified by - D.C.T.
Classification checked by -
Records compiled from original notes by - D.C.T.
Checked by - D.C.T.
Checked by - H.C.S.
Examined by - W.A.W.

PLATE I

became very weak, but it could be lighted with a match at times for six weeks. Three of the other holes came within 100 feet of this hole, and in three directions from it, but no trace of gas was found in any of them. Hole No. 54, 100 feet downstream from hole No. 4, was driven 40 feet deeper than No. 4 to develop the lower strata. It gave excellent core recovery (97 per cent) and satisfactory pressure test. At 100 feet above the bottom of the hole the pressure fell only from 100 pounds to 90 pounds in a minute.

Gas was struck in hole No. 34 at elevation 330. It developed a gage pressure of 30 pounds and caused the water to bubble around the casing, but could not be lighted. When the casing was removed from the hole no further trace of gas could be detected.

Character of Rocks.

The very existence of the shoal, with its abnormal width of stream, great slope (6 feet to the mile over Big Muscle Shoals, and 3.5 feet to the mile over Little Muscle Shoals), and its shallow depths over rock bed, is evidence of the hardness of the bed rock. Outcroppings along the bluff bank throughout the shoals and for many miles below, show good hard rock with close, tight seams between strata. The exposed bed rock in the shoals is uniformly a highly siliceous limestone, running as high as 90 per cent silica. For 7 miles in either direction from Dam No. 2, the bluff outcrop is of the same character. Further downstream than this the bluff stone is a good quality fossiliferous limestone. From about 7 miles above Dam No. 2 up to Dam No. 3, workable limestone outcrop alternates with the siliceous material. On both banks of Dam No. 3 the bluff is limestone of good quality, the strata being thin on the right bank but fairly thick ledges on the left bank. There is nothing in the superficial appearance of the entire stretch to indicate the existence of material that would be faulty for foundations. Certainly, the results of the diamond drilling bear out this view with respect to the actual sites. Foundation conditions are practically perfect. In the river bed there are a few thin seams between the top strata, which are either void or filled with soft material, with here and there one of great enough extent to be styled a cavity. The cut-off section of the dam will be so designed as to cut off leakage through the seams and cavities near the surface, the deeper ones can easily be grouted.

Joseph Eggleston Johnston.

BY

Capt. O. N. Sohlberg,
Corps of Engineers.

Joseph Eggleston Johnston was the eighth son of Judge Peter and Mary Johnston of Virginia, and was born at Longwood, Prince Edward County, on February 3, 1807. His grandfather emigrated from Scotland to Virginia in 1727. His father ran away from college during the Revolution and joined the legion of "Light Horse" Harry Lee, with which he served until the end of the war. From this period dates the friendship between the families of the Lees and Johnstons, whose sons were destined to become great leaders in the same cause.

At the age of 18, Johnston realized his ambition for a military career in receiving an appointment to the United States Military Academy, which he entered in 1825. Robert E. Lee was in the same class. The two Virginians became fast friends. Johnston was an earnest student, but was prevented by weakness of his eyes from using them at night. He was graduated thirteenth in a class of forty-six.

Johnston's first service was with the Fourth Artillery, then in garrison at New York and Fortress Monroe. In 1832 he took part in the Black Hawk War under General Scott. He now served at several forts along the Atlantic Coast and on topographical duties until 1836, when he was ordered to accompany General Scott as a member of his staff in the expedition against the Florida Indians. After this unsuccessful expedition there seemed to be no prospects of active service or promotion, so Johnston tendered his resignation and entered the Government employ as a civil engineer. However, the Indian trouble broke out again immediately, and Johnston volunteered for service. He was assigned to accompany an exploration expedition to the interior of Florida. This expedition was almost wiped out by Indians, and those of the party that were saved owed their lives to the bravery of Johnston

and a few regulars. For this gallantry Johnston was appointed First Lieutenant in the Topographical Engineers. On his return from Florida, Johnston performed various duties of the Topographical Engineers in river improvements, boundary marking between Texas and the United States, and survey of the Great Lakes. Again, after another detail to Florida, under General Worth, he was assigned with the survey of the boundary between the United States and the British Provinces, and later to the coast survey.

In 1845 he married Miss Lydia McLane, of a prominent Maryland family. There were no children born to them.

Johnston entered the Mexican War as a Captain of Topographical Engineers in General Scott's expedition. Soon after the start of the inland march Johnston was appointed Lieutenant Colonel of Voltigeurs, a new regiment of regulars, but still rendering services as an Engineer when needed. Before Cerro Gordo he was twice wounded—his usual fortune in actions—while making a reconnaissance. For this he was made Brevet Major and, subsequently, Colonel of Regulars. He was again breveted for gallantry at Chapultepec. He served in this War in the Siege of Vera Cruz and the battles of Contreras, Churubusco, Molino del Rey, and the taking of Chapultepec and Mexico City.

After the war Johnston engaged in topographical services in Texas and on the Western river improvements. In 1855, he was commissioned Lieutenant Colonel of a new cavalry regiment. With this regiment he served in the West and acted as Inspector General of the Utah Expedition in 1858. In 1860, the Quartermaster General died and, as he was next in rank to General Scott, who was old, it was necessary that an able man take his place in case he should have to fill the position of Commander of the Army. General Scott submitted four names of officers best fitted to fill this office. These were: R. E. Lee, A. S. Johnston, J. E. Johnston, and C. F. Smith. J. E. Johnston was finally chosen. His term of office was short lived, for, at the outbreak of the Civil War he tendered his resignation to follow his native State.

The details of Johnston's part in the Civil War are a matter of history. He was first commissioned Major General of Volunteers in the Army of Virginia, but later, in August, 1861, he was made one of the five full Generals of the Confederacy, with command of the main army in Virginia. He, with Beauregard, won the first great victory of the Confederacy at Manassas, giving his cause time to organize for the coming conflict. He foiled McClellan at York-

town, and might have been successful in destroying him at Seven Pines, but Johnston was wounded and his plan of battle was not carried out. Nearly a year later, his wound still troubling him, Johnston was sent to cope with the difficult situation in Tennessee and, later, to endeavor to raise the Siege of Vicksburg. In 1863, after the defeat at Chattanooga, he was put in command of the Army of Tennessee to halt Sherman's march on Atlanta. Johnston's Fabian tactics kept the superior Union Army from advancing more than a mile a day; but his methods were not acceptable to the administration and Hood replaced him. After the Battle of Nashville, Johnston was reinstated to oppose Sherman's northern movement with but the shadow of an army.

After the close of the Civil War, Johnston engaged in civil pursuits. In 1877 he was elected to Congress, and in 1887 was appointed United States Railroad Commissioner by the President. He died at Washington, D. C., on the 21st of March, 1891.

Consolidation of Trenches, Localities and Craters After Assault and Capture.[1]

1. Consolidation of a Captured System of Trenches.

The capture of a system of hostile trenches is an easy matter compared with the difficulty of retaining it. A thorough knowledge of the principles, a careful study and correct use of the natural features of the ground, and a detailed preparation and organization of the work, are necessary; but success will only result if there is also an absolute determination on the part of all ranks to get the work done promptly at all costs.

The principles of the consolidation of captured trenches are, briefly, as follows:

(*a*) To establish a series of strong points or centers of resistance, wired all round and mutually supporting each other according to the ground. These points should be provided with machine or Lewis guns at once.

(*b*) To provide good communication to the rear from these points.

(*c*) To fill in all hostile trenches within bombing distance of the points occupied.

(*d*) To establish, if possible, simultaneously with the consolidation of strong points in the front line, a number of supporting points in rear. These points should, if the ground is favorable, be placed to cover the intervals between the works in the front line.

(*e*) The strong points can later be connected to form a continuous front line.

The above principles must be applied with due regard to the natural tactical features of the ground. The satisfactory siting and consolidation of a position will largely depend on the power possessed by the officers on the spot to recognize during the various stages of a battle the minor features of real tactical importance. This ability is only acquired by previous training, and is a quality

[1]With a note on rapid wiring. 1916.

which every officer must study to possess. The size and trace of the "strong points," as well as the intervals between them, will vary according to the lie of the ground and the plan of the hostile trenches captured. During the process of consolidation concealment from artillery observation is of importance.

The first essential is speed in rendering the captured position strong enough to resist the first counter-attacks. It is therefore necessary that a definite plan should be decided on beforehand as to which points first require attention. This can be done, in the majority of cases, with great accuracy from maps and aeroplane photographs and from a study of the ground from any point in our lines which commands a view of it. In the case of craters, the forecast of the tunnelling officers must be obtained.

Although it is usually advisable that assaulting troops should be relieved as soon as possible, this must not be taken to imply that the duty of securing ground gained is the task only of the relieving troops. It is an unsound principle for troops to *expect* to be relieved immediately after an attack, as it wastes valuable time at a critical period when speed in work is essential. It must be understood that troops which take a position must commence the work of consolidation at once.

The distribution of engineer detachments requires to be carefully considered beforehand. In all cases of an assault or advance, where it is intended to secure the ground gained, the troops destined for the purpose should include a detachment of engineers, the commander of which should be detailed previously and attached to the staff of the unit or formation concerned.

Garrisons must hold on to their ground; they have nothing to fear from being outflanked.

2. Consolidation of Localities.

During an advance, when it becomes necessary to consolidate some locality of tactical importance, such as a village or wood, the same general principles hold good as in the consolidation of a system of trenches. Some notes on the particular points that require attention in the case of villages and woods are appended.

Villages. Enlargements from even small scale maps give very accurate plans of most villages and make it possible to plan the defence in sufficient detail beforehand. It is essential that subordinate commanders should be provided with such plans, in order

that the general idea of the defence may be quickly and properly understood.

The order of urgency of work is as follows:

(*a*) Barricade and picket all exits. Establish center of resistance near exits to cover approaches or any streams or tracks which might serve to guide a counter-attack. Commence work on keep, preferably at village cross-roads. Barricade roads.
(*b*) Reconnoiter for cellars.
(*c*) Establish communications, giving cover from view, radiating from keep to outer centers of resistance, and from keep to the rear.
(*d*) Construct bombproofs in cellars at centers of resistance and keep—false roofs to cellars, etc.
(*e*) Complete keep.
(*f*) Improve communications at (*c*) above, to give cover from fire.
(*g*) Make lateral lines of communication between centers of resistance.

Centers of resistance should be established (if it is possible to do so) to the flank of conspicuous buildings likely to afford good targets for hostile artillery fire. In the case of keeps in villages, this is often impossible owing to the presence of church spires. It is, however, preferable to have a keep, even with this disadvantage, that is central, accessible, and strong against infantry assault. It should be remembered in this connection that by the time hostile infantry can assault a village keep, hostile artillery fire will necessarily have ceased.

Woods. As in the case of villages, plans should be prepared of the locality.

There has been much discussion in the past as to what part of a wood should be occupied. Experience has proved that, owing to the great advanges afforded by cover from view, the position to take up in a wood is, just so far within the outer edge as will permit of good view into the open. In this connection it should be remembered that in course of time shell and rifle fire thins out the edges of woods considerably. It is therefore advantageous in the first instance to take up positions slightly in rear of those which may appear at the moment to be most advantageous.

If, as is often the case, the wood is surrounded by a hedge, there is a natural tendency to make trenches against this hedge. This is to be avoided. A hedge forms a very good obstacle against assault, with the addition of a little wire. If it screens the view it can be quickly thinned.

The order or urgency of work is as follows:

(*a*) Establish centers of resistance for all-round defence at the corners and salients of the wood. These are the points which are most liable to counter-attack.
Establish central reserve, reconnoiter, blaze and clear communications.
The defence of a wood should be very active, and counter-attacks must be launched against any hostile troops that may reach the edge of the wood, in order to prevent a lodgment that places the enemy on equal terms.

(*b*) Establish intermediate centers of resistance and lateral communication.

(*c*) Establish central keep at junction of rides, or on near edge of clearing.

In the case of large woods and forests, where the general line of defence runs through a wood, a line of strong centers of resistance should be established across the wood, if possible behind a road or other clearing. The near edge of the clearing should be entangled, and the intervals between the "centers" should be swept by fire. As time permits "rays" should be cleared, radiating from the centers of resistance and crossing similar "rays" from adjoining centers, so as to add to the depth of the field of fire.

These rays should be wired and obstacles arranged, so as to break up an attack and force the attackers into the openings.

A line of intermediate centers, communications, etc., should also be established, as indicated in (*b*) above.

3. Occupation of Craters.

i. The occupation and consolidation of mine craters presents many difficulties, and all ranks should understand the principles to be acted upon in the event of the explosion of mines on their front.

ii. Craters are usually formed as a result of one of the following mining operations:

(*a*) An attack by us on the enemy's trenches;
(*b*) An attack by the enemy on our trenches;
(*c*) Underground fighting.

iii. The possession of a crater offers the following advantages:

(*a*) It can be turned into a strong point capable of holding a small garrison;
(*b*) It gives command of the ground in the vicinity;
(*c*) It forms a considerable obstacle.

iv. (*a*) When mines are exploded by us in connection with an attack on the enemy's trenches, our object should be to seize and hold the whole of the mine crater or craters, or a line in front of them. The latter plan is usually the best, and the craters in rear can then be turned into strong points.

(*b*) When craters are formed as the result of an attack by the enemy on our trenches, or in the course of underground fighting, our object will usually be to seize and hold the near "lip" of the crater.

Parties must be rushed out at once to seize the lip. It may be impossible to open up communication to these parties till after dark. They should, therefore, take sufficient grenades, water, etc., and must be prepared to hold on though isolated.

v. Before the explosion of a mine a forecast should be made of the state of affairs to be expected after the explosion, and all details of probable requirements should be worked out. These would include:

(*a*) The formation of dumps of engineer materials as close up as possible.

(*b*) The organization of working and carrying parties.

Work should start immediately after the explosion of the mine, and no time should be lost in turning into account the quiet interval which usually follows the explosion.

The personnel of engineer companies should be freely used for this work under instructions given through the General Staff.

vi. The following are the main points to be attended to in the actual consolidation of the craters:

(*a*) All trenches should be strutted as they are constructed. Special frames for this purpose must be made beforehand.

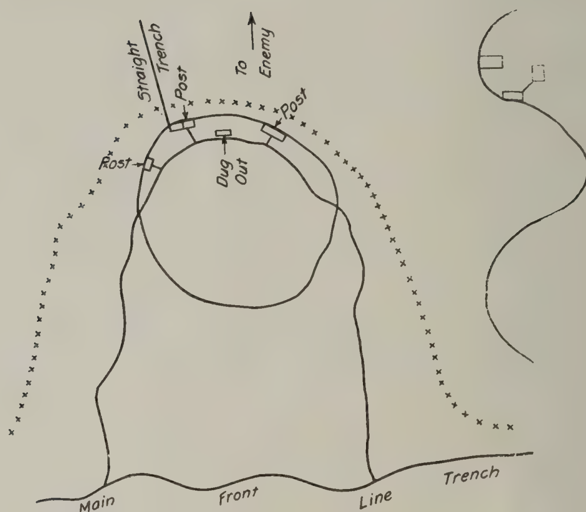
(*b*) All works on a crater, whether inside or outside the "lip," should be provided with a parados.

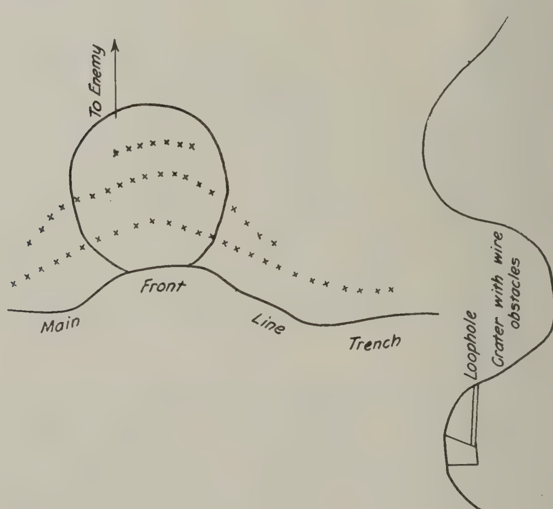
(*c*) Dug-outs should be made by tunnelling into the sides and not at the bottom of the crater.

(*d*) At least two communication trenches should be constructed leading into each crater.

Entrances to craters should be made at the sides and not through the rear "lip."

(*e*) All trenches leading up to a crater from the enemy's line should be straightened or filled in for a distance of


Straight Trench
Post
To Enemy
Post
Post
Dug Out
Main
Front
Line
Trench

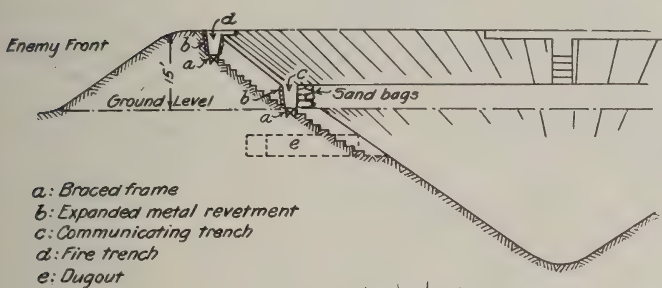

To Enemy
Front
Main
Line
Trench
Loophole
Crater with wire obstacles

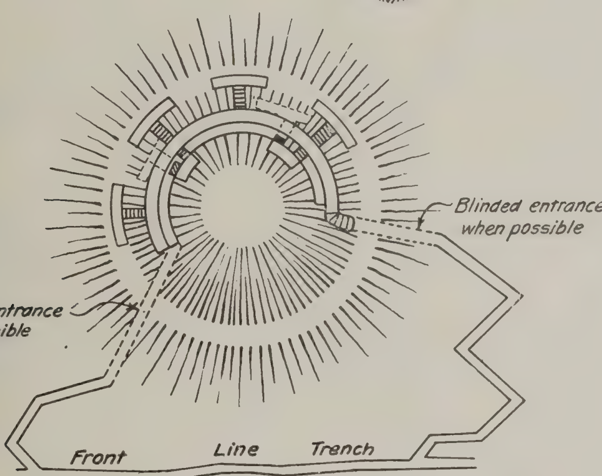
at least 40 yards from the position of the defenders, so as to keep the enemy bombers at a distance.

This work can usually be carried out with the least difficulty immediately after the explosion.

(*f*) Collapsible knife-rests, French wire and other forms of portable wire entanglement, should be brought up in large quantities and thrown over the "lip" of a crater.

ELEVATION





PLAN

PLATE A: Sketch of Front Lip of Crater Prepared for Defence.

vii. There are two main methods of holding craters:

(*a*) *Method "A."* (See upper sketch on page 212 and Plate A.)

This method should usually be employed after the explosion by us of a mine in the enemy's trenches or in the area where it is known that the enemy is not engaged in mining.

The front "lip" of the crater is held by means of several posts. Two communication trenches lead into the crater, one on each side, and give lateral communication between the posts. One or

two dug-outs are constructed in the sides of the crater.

(*b*) *Method "B."* (*See lower* sketch on page 212 and Plate B.)

This method should usually be employed when the enemy has exploded a mine in or near our trenches, or when we have exploded a defensive mine close to our own trenches.

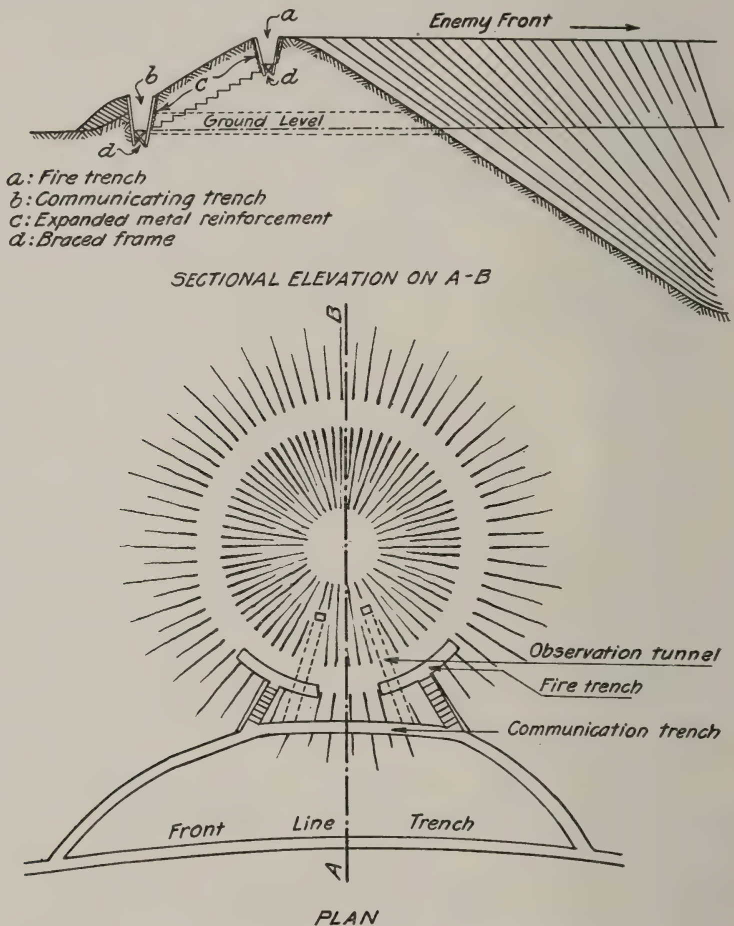


PLATE B: Sketch of Rear Lip of Crater Prepared for Defence.

The rear "lip" of the crater is held. Wire is thrown inside the crater. One or two loop-holes are cut through the rear "lip" so as to command the inside of the crater.

Plate C shows a scheme for converting the area behind the lips of a series of craters, which have been occupied, into a strong post.

The importance of rendering the means of access to the lip secure from bombing attack is not always recognized.

viii. Work should be carried out in the following order:

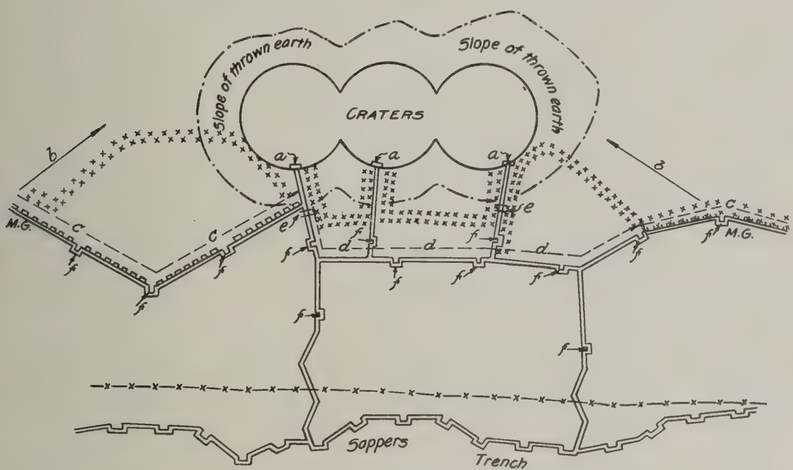
(*a*) Construction of one or two posts in the "lip" of the crater;

(*b*) Wiring the front of posts and filling in or straightening trenches leading from it towards the enemy;

(*c*) Digging of communication trenches up to the crater.

And, if far lip has been occupied—

(*d*) Digging trench for lateral communication inside the crater;



KEY: a: Observation and bombing posts
b: Direction of M.G. fire
c: Fire trench
d: Bombing trench
e: Bridge traverse to check enfilade fire
f: Traverse with loophole for fixed rifle to fire down trench

PLATE C: Sketch plan showing proposed system of defence by bombing trenches behind craters where no field of fire can be obtained.

Scale of Yards

10 0 50 100

(*e*) Completion of wiring front of crater and construction of further posts in far "lip";

(*f*) Construction of dug-outs;

(*g*) Improvements to the above.

It should usually be possible to do (*a*), (*b*) and (*c*) together.

4. Notes on Rapid Wire Entanglements.

One of the first requirements in consolidating a position is to get some wire out in front of it.

The following general principles regarding the construction of wire entanglements should be observed:

(i.) The rear edge of the entanglement should be about 20 yards from the trench; if the trace of the entanglement is irregular and does not follow the trace of the trench, it will make the task of the hostile artillery more difficult.

(ii.) The depth of the entanglement should be as great as possible, and at least 30 feet. The wire available should be expended in forming a deep entanglement rather than a "heavy" one (*i. e.*, one with a large amount of wire between each set of posts). The construction of two belts with an interval between them, rather than one belt of twice the depth, gives the hostile artillery a deeper target to destroy, without increasing the material required for constructing the entanglement, except by one row of pickets.

(iii.) There will seldom be time in rapid wiring to "dig in" the wire for concealment. Every advantage should be taken, however, of natural folds in the ground, long grass, or brushwood, or other means of concealment.

(iv.) Wire entanglements should be 2 feet 6 inches to 3 feet high.

(v.) The posts in a row should be about 6 feet from each other, and the rows about 6 feet apart. If wooden posts are used they must be strong; light posts are useless.

(vi.) The difficulties of crossing an entanglement are increased if it is not too regular; *e. g.*, if the heights of the posts above ground and the distances between them are varied. For rapid wiring drill, however, a regular entanglement is easier to construct.

To ensure that an obstacle can be erected with rapidity and in silence, every one of the working party must know what he has to do and work so that he does not get in the way of the others.

This necessitates some form of *drill*. There are a large number in use, of which a selection is given below. The following notes and rules will be found useful in carrying out any form of drill for constructing wire entanglements:

(i) The party should, as far as possible, work so that the obstacle is always between them and the enemy. Each wiring party should have a double sentry lying down about 30 or 40 yards towards the enemy to prevent

patrols sniping or bombing the party. If circumstances necessitate it, a special covering party should be provided.

(ii.) The party should work extended and not bunched together.

(iii.) Large parties, in which each group of men has only one operation or duty to perform, will erect entanglements quicker than a small party, in which each man has several duties to perform in succession, unless latter is very well drilled.

(iv.) The best *unit* of entanglement is about 40 or 50 yards long. Its construction can then be controlled from one point. This distance is also a convenient interval to leave small gaps for patrols.

(v.) A line of posts is best laid out at night by putting down a tape or string with the intervals of the posts marked by bits of rag or sandbag tied on to it.

(vi.) The end of a coil of barbed wire will be found secured on the drum tucked under the standing part. In the dark it is very hard to find and release. Coils should therefore be prepared by daylight. A good method is to attach a piece of string to the end, uncoil the roll half a turn, re-coil it on a piece of old sandbag and fasten it up by the string. The end of the wire can then be readily found in the dark. The pieces of tin on the wooden drums should be removed to prevent noise. It may be found convenient, to make carrying easier, to re-coil the barbed wire in smaller coils on a stout stake.

(vii.) Pickets should be made up into bundles of one-man loads. They should be firmly tied with plain wire or brought up in sandbags. The latter is the surer way of keeping them together, at any rate with small wooden pickets. A drum of barbed wire is best carried over the shoulder, with a stout stake passed through it, which also serves for uncoiling the wire. Pickets and wire should be dumped by the carrying party, outside the trench, behind the center of the length to be wired.

(viii.) Mauls, if used, should be muffled by nailing on a leather face or with sandbags. About 8 thicknesses of sandbag material are necessary to be of any use.

(ix.) Equipment should not, unless necessary, be worn by wiring parties, as it is liable to cause noise.

(x.) STAYS AND HOLDFASTS (*see* Fig. 1).

Forward stays are not absolutely necessary if the entanglement posts are well driven in. They are usually required with iron screw posts, which are not very

stiff unless driven in up to the bottom eye. Forward stays can not be put on, without great loss of time, until the fence on the first row of posts has been completed; for they would interfere with the fence wires being looped over the posts.

Back stays should invariably be provided and anchored well back, so as to resist any attempt to pull the entanglement away by grapnels.

Side stays at the ends of separate lengths of entanglement are usually desirable.

Pickets used as holdfasts for stays should be "staggered," *i. e.*, not driven in vertically, but inclined away from the post that they stay.

(xi.) When stringing horizontal wires for an apron on a stay or diagonal, the latter should be given a kink or bend at the places of crossing, so that there will be less chance of the wires slipping down. The horizontal wires may be secured by binding wire, or by taking a bight and looping it round the stay. The coil should not be passed over and under, as this is a slow process.

NOTES WITH REFERENCE TO IRON SCREW POSTS AND PICKETS.

(*a*) The posts are 5 feet long with four eyes, the pickets are 3 feet 6 inches long with two eyes, or 15 inches long with a loop at the end. If the ground is soft, the posts can be screwed in 2 feet deep or more.[1]

(*b*) In rapid work the wire can simply be placed in the eye by forming a loop in the wire and slipping it over the post. It is not intended that the wire should be threaded through the eye. If time allows, the horizontal wires can be put on slack, and when the fence is strung the post can be given a complete turn, so as to prevent the wire slipping out should it be cut; or the barbed wire may be twisted round the posts, through an eye, as it is put on; or it may be secured to the eyes by binding wire.

(*c*) To permit of the loops being slipped over the posts, it is obvious that the lowest wire in a fence must be put on first, and no forward or back stays can be fixed until the fence has been completed.

(*d*) Care must be taken that all the posts are originally screwed in so that the eyes point the same way, otherwise delays will occur in the wiring.

(*e*) Loose bundles of iron screw posts and pickets can not be carried noiselessly. It is advisable, therefore, to wrap

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[1]Angle iron posts are 5 feet 10 inches and 3 feet 6 inches long.

them round with a sandbag, secured by a light turn of wire with the ends twisted together. Enough end to this wire should be left so that it can be untwisted by hand without pliers.

(*f*) Short stakes or bats must be provided to fit the top eye of the posts in order to screw them in. The helves of the entrenching implement serve the purpose.

EXAMPLES OF WIRE DRILLS.

Picket is used to mean a short picket used as a holdfast.

Post is used to mean a longer upright.

Fence is used to mean a series of wires on a row of posts.

The conventional signs used in the diagrams are explained in Fig. 2.

In all the drills given, unless otherwise stated, it is assumed that:

(*a*) The length to be erected is 50 yards;

(*b*) The stores required are collected at a point behind the center of the length in a convenient order;

(*c*) The line of the fence has been marked or indicated;

(*d*) The drums of wire are opened and the ends ready;

(*e*) Bars or sticks are run through the drums, so that the wire can be uncoiled readily;

(*f*) Short sticks for screwing in the pickets are carried by the men requiring them (or mauls if wooden or angle iron pickets are used);

(*g*) All wirers have hedging gloves and wire cutters; and have their legs protected by gaiters or sandbags;

(*h*) Each number consists of two men who work together, and the numbers commence work in succession at a suitable interval (say 4 posts apart). Thus Nos. 2 move off as soon as Nos. 1 have the desired start, Nos. 3 at the same interval behind Nos. 2.

(*i*) All work is commenced on the left;

(*j*) The men who put the top wire on a fence stay the end post to short pickets;

(*k*) On completion of each operation or "duty" detailed in the drill, all men should return to a fixed place, in order to prevent confusion, if some work faster than others;

(*l*) Spare men are at hand to replace any casualties.

The drills are primarily intended for use with iron screw posts, but can be used for wooden or angle iron posts with slight modifications. If the soil permits of posts being screwed in to the

bottom eye, no stays are necessary, and three horizontal wires in the fence, instead of four, will be sufficient.

No estimates of stores required are given, as the distance apart of the posts and the amount of wire used must depend on what is available.

Drill No. 1. Double Apron Entanglement.

(See Figure 3.)

Working Party: 12 Men Exclusive of Non-commissioned Officers.

First Duty.

Nos. 1. Lay posts in position on ground A.
Nos. 2. Front rank—assists Nos. 1;
Rear rank—holds up posts for Nos. 3 to screw in.
Nos. 3. Screw in posts, separately.
Nos. 4. Lay front and rear pickets in position.
Nos. 5. Screw in front pickets, B.
Nos. 6. Screw in rear pickets, C.

Second Duty.

Nos. 1. Bottom wire of fence, A.
Nos. 2. Second wire of fence, A.
Nos. 3. Third wire of fence, A.
Nos. 4. Top wire of fence, A.
Nos. 5. Front diagonal between A and B.
Nos. 6. Rear diagonal between A and C.

Third Duty.

Nos. 1. Top horizontal wire on front diagonals, AB.
Nos. 2. Second horizontal wire on front diagonals, AB.
Nos. 3. Bottom horizontal wire on front diagonals, AB.
Nos. 4. Top horizontal wire on back diagonal, AC.
Nos. 5. Second horizontal wire on back diagonal, AC.
Nos. 6. Bottom horizontal wire on back diagonal, AC.

This drill involves Nos. 5 in "Second Duty," and Nos. 1, 2 and 3 in "Third Duty," working in front of the fence.

In the "First Duty," No. 2 rear rank holds up a post for No. 3 front rank to screw in until it gets a bite in the ground. He then holds up a post for No. 3 rear rank, etc.

This obstacle and others of the same nature can be deepened by adding similar bays behind it. The posts in successive bays should cover the intervals between those in front of them. (*See* Fig. 4.)

If two bays are made, the obstacle can be increased by tossing loose wire into the valley between the posts.

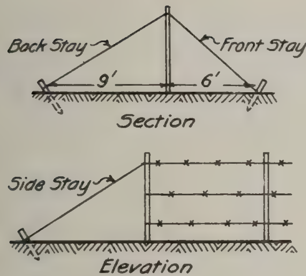

Fig. 1

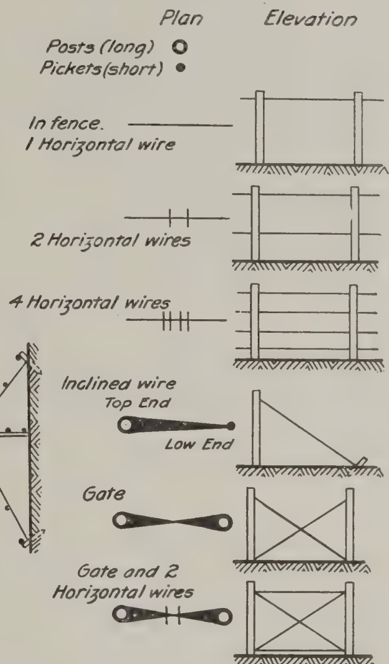

Fig. 2
Conventional Signs Used in Plates

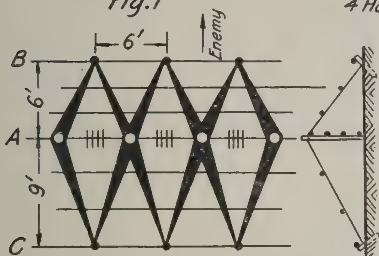

Fig. 3

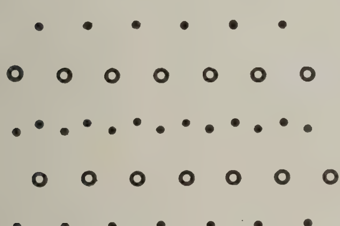

Fig. 4

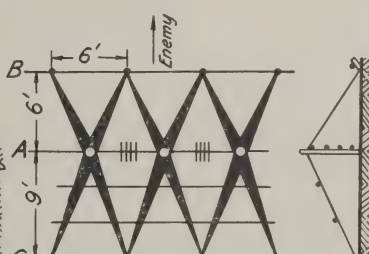

Fig. 5

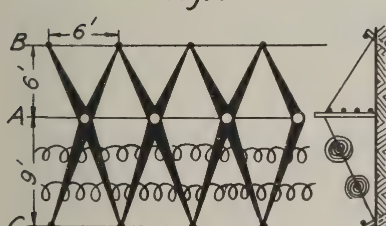

Fig. 6

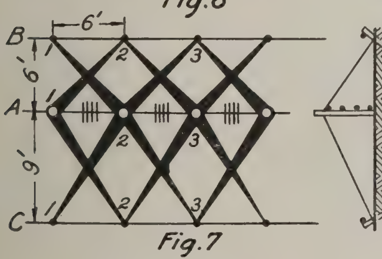

Fig. 7

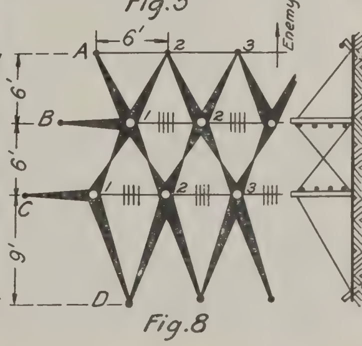

Fig. 8

Drill No. 2. Trip, Fence and Apron.

(*See Figure 5.*)

Working Party: 10 Men, Exclusive of Non-commissioned Officers.

First Duty.

Nos. 1. Lay posts in position, A.
Nos. 2. Hold up posts.
Nos. 3. Screw in posts.
Nos. 4. Bring up and screw in front pickets, B.
Nos. 5. Bring up and screw in rear pickets, C.

Second Duty.

Nos. 1. Front trip wire on pickets, B.
Nos. 2. Bottom wire on fence, A.
Nos. 3. Second wire on fence, A.
Nos. 4. Third wire on fence, A.
Nos. 5. Top wire on fence, A.

Third Duty.

Nos. 1. Front diagonal between A and B.
Nos. 2. Back diagonal between A and C.
Nos. 3. Top horizontal wire on the diagonals, AC.
Nos. 4. Second horizontal wire on the diagonals, AC.
Nos. 5. Bottom horizontal wire on the diagonals, AC.

Nos. 1 have to work in front of the fence in "Third Duty."

Drill No. 3. Trip and Fence.

(*See Figure 6.*)

Working Party: 16 Men, Exclusive of Non-commissioned Officers.

First Duty.

Nos. 1. Screw in posts 6 feet apart, A.
Nos. 2. Screw in pickets B and C; B first.
Nos. 3. Trip wire, B.
Nos. 4. Bottom wire of fence, A.
Nos. 5. Second wire of fence, A.
Nos. 6. Third wire of fence, A.
Nos. 7. Top wire of fence, A.
Nos. 8. Diagonal wire between A and C.

Second Duty.

Nos. 1. Diagonal wire between A and B.
Nos. 2. Trip wire, C.
Nos. 3. Uncoil loose wire.
Nos. 4. Uncoil loose wire.
Nos. 5. Toss in loose wire uncoiled.
Nos. 6. Toss in loose wire uncoiled.
Nos. 7. Fasten loose wire.
Nos. 8. Fasten loose wire.

In the "Second Duty," Nos. 1 have to work in front of the fence.

Nos. 3 and 4 uncoil the loose barbed wire on the ground well clear of the entanglement. Six coils for each 25 yards.

Nos. 5 and 6, with large wooden pickets, lift the loose wire and toss it on to the entanglement.

Nos. 7 and 8 spread the loose wire out and fasten it by twisting a bight at intervals to the diagonals and fence wires.

Drill No. 4. Fence, with Crossed Diagonals and Trips.

(See Figure 7.)

Working Party: 14 Men, Exclusive of Non-commissioned Officers.

The pickets are placed opposite the posts.

This drill involves four men working on the enemy's side of the fence.

First Duty.

Nos. 1. Screw in posts, A.
Nos. 2. Screw in pickets: B first, then C.
Nos. 3. Trip wire, B.
Nos. 4. Bottom wire of fence, A.
Nos. 5. Second wire of fence, A.
Nos. 6. Third wire of fence, A.
Nos. 7. Top wire of fence, A.

Second Duty.

Nos. 1 and 2. Prepare posts in next length.
Nos. 3. Front diagonal between A and B, commencing at picket B, B_1, then to A_2, B_3, etc.
Nos. 4. Front diagonal between A and B, commencing at top of post A_1, then to B_2, A_3.
Nos. 5. Back diagonal between A and C, commencing at C_1, then to A_2, C_3, A_4, etc.
Nos. 6 and 7. Back diagonal between A and C, commencing at top of post A_1, then to C_2, A_3, etc.

Drill No. 5. Successive Rows of Fences.

(See Figure 8.)

Working Party: 12 Men, Divided into Four Groups of 3 Each, W, X, Y, Z.

The posts must be prepared by attaching binding wire to the bottom eye, to this the vertical diagonals between the fences are made fast.

First Duty.

Group W. Lay out posts in row, B.
Group X. Screw in above.
Group Y. Lay out pickets in row, A.
Group Z. Screw in above.

Second Duty.

Group W. Lay out posts in row, C.
Group X. Screw in above.
Group Y. Bottom wire of fence, B.
Group Z. Trip wire on row, A.

Third Duty.

Group W. Second wire on fence, B.
Group X. Third wire on fence, B.
Group Y. Top wire on fence, B.
Group Z. Front diagonal between A and B.

Fourth Duty.

Group W. Bottom wire of fence, C.
Group X. Second wire of fence, C.
Group Y. Third wire of fence, C.
Group Z. Top wire of fence, C.

Fifth Duty.

Group W. Diagonal between B and C, bottom of C_1 to top of B_1, bottom of C_2, etc.
Group X. Second diagonal between B and C, top of C_1 to bottom of B_1, top of C_2, etc.
Group Y. Lay out and screw in pickets, D; or lay out row of posts, D, if the fences are to be continued.
Group Z. Diagonal between C and D; or screw in above, etc.

In "Third Duty," Z, and in "Fifth Duty," W and X, work on enemy's side of fence.

In "Fifth Duty," W and X loop the diagonals over top of pickets and make them fast to the bottom eye by binding wire.

Instead of putting the criss-cross diagonals between fences B and C as above, which involves binding wire and takes some little time, it would be sufficient if time presses to stay the pickets merely by connecting the heads. (See Fig. 9.) "Gooseberries," etc., can be thrown into the space between B and C.

Another variation is to put loose wire or French wire between fences B and C and criss-cross plain wire to connect the tops of the pickets. (See Fig. 10.)

A further variation can be introduced by placing the posts so as to form squares instead of triangles. (See Fig. 11.)

Drill No. 6. Double Fence.

(See Figure 12.)

Working Party: 28 Men, Exclusive of Non-commissioned Officers.

This entanglement is designed for stout wooden posts well driven in, or screw posts screwed in down to the bottom eye; no holdfast pickets are then required.

The drill only requires one duty from each pair of men.

The apron is of a different pattern to those previously given, the wires miss alternate pickets.

Three horizontal wires can be used for the fence, instead of the "gate" pattern shown.

Order of Work.

(1) Under superintendence of two non-commissioned officers, all hands carry and place the posts on the ground.

(2) Nos. 1 drive or screw in posts in front fence, A.
Nos. 2 drive or screw in posts in back fence, B.
Nos. 3 bottom wire 3 of fence, A.
Nos. 4 diagonal wire 4 of fence, A.
Nos. 5 diagonal wire 5 of fence, A.
Nos. 6 top wire 6 of fence, A.
Nos. 7 bottom wire 3 of fence, B.
Nos. 8 diagonal wire 4 of fence, B.
Nos. 9 diagonal wire 5 of fence, B.
Nos. 10 top wire 6 of fence, B.
Nos. 11 apron wire 11.
Nos. 12 apron wire 12.
Nos. 13 apron wire 13.
Nos. 14 festooned wire 14.

Drill No. 7. Ordinary Low Entanglement.[1]

(See Figure 13.)

Working Party: 30 Men in 10 Groups, with a Non-commissioned Officer.

Group A, front row of pickets, A.
Group B, straight wire, A, row of pickets.

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[1]A low entanglement is not, as a rule, sufficient by itself, but may be combined with a high entanglement (see Figs. 15, 16, 17, and 18).

Group C, second row of pickets, C.
Group D, zig-zag wire A_1, C_1, A_2, C_2, etc.
Group E, loose wire on zig-zag A_1, C_1, A_2, C_2, etc.
Group F, straight wire on C row of pickets.
Group G, third row of pickets, G.
Group H, zig-zag wire G_1, C_1, G_2, C_2, etc.
Group J, loose wire on zig-zag G_1, C_1, G_2, C_2, etc.
Group K, straight wire on G row of pickets.

Pickets may be 12 to 18 inches out of the ground and 3 feet apart.

Drill No. 8. French Wire Obstacle.

(*See Figure 14.*)

The obstacle consists of two rows of French wire, placed just far enough apart for a man to pass between them. Each coil is stapled down in five places—at each end, and at ¼, ½, and ¾ of its length. When two coils meet, the same staple fastens down both coils.

Posts, 5 feet long, are driven through the center of the coils in five places, as in the case of the staples; the ends of adjoining coils are interlaced a little so that the post will go through both.

A strand of barbed wire is run along the top of each row and fastened to the posts with a round turn. It is pulled as taut as possible and twisted on to the French wire, by a staple, peg or wire cutters, close to each post, and in several places between the posts.

One or more strands of barbed wire are run along to the front as an "apron."

Diagonal wires are run from the tops of posts of the front row to tops of posts of second row.

Working Party: 24 Men in Three Parties, with Non-commissioned Officer.

Front Row.

Party A. 1 holds end of French wire and staples it down.
2 pulls wire out 20 yards.
3 shakes wire clear of obstructions and puts in staples ¼, ½, and ¾ way along.

Party B. 1 mauls in anchorage pickets and posts.
2 holds posts.
3 supplies posts.

Party C. 1 uncoils barbed wire.
2 makes fast end to anchorage and twists wire round tops of pickets.
3 twists barbed wire on to the French wire.

Party D. 1 runs coil of barbed wire along the front.
2 and 3 twist it on to the front of the French wire.

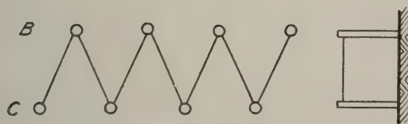


Fig. 9

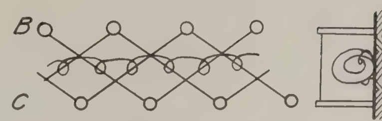


Fig. 10

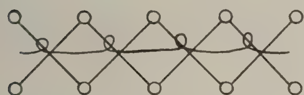


Fig. 11

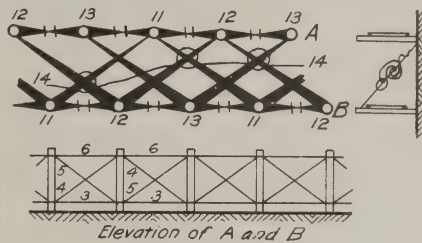


Fig. 12

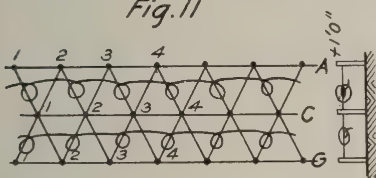


Fig. 13

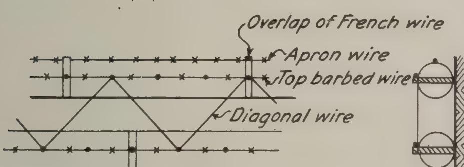


Fig. 14

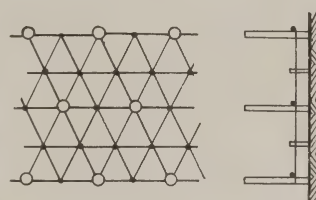


Fig. 17

Fig. 15

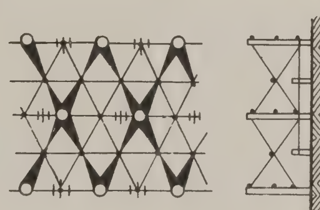


Fig. 18

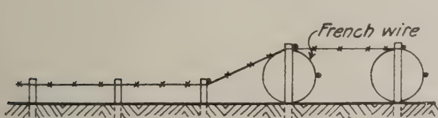


Fig. 16

Back Row.

Party E. Same as A.
Party F. Same as B.
Party G. Same as C.
Party H. 1, with coil of barbed wire, moves between the two rows, uncoiling the wire.
2 and 3 move on either side of the entanglement and make this barbed wire fast to the posts as the diagonal, while H_1 holds the coil so that H_2 and H_3 can reach it.

The obstacles described above can be combined in various ways either by placing one behind the others (see Figs. 15 and 16), or by placing a high wire entanglement over a low one (see Figs. 17 and 18).

Miscellaneous Notes.

Raising the Sunken Dismantled Steamship "City of Panama."

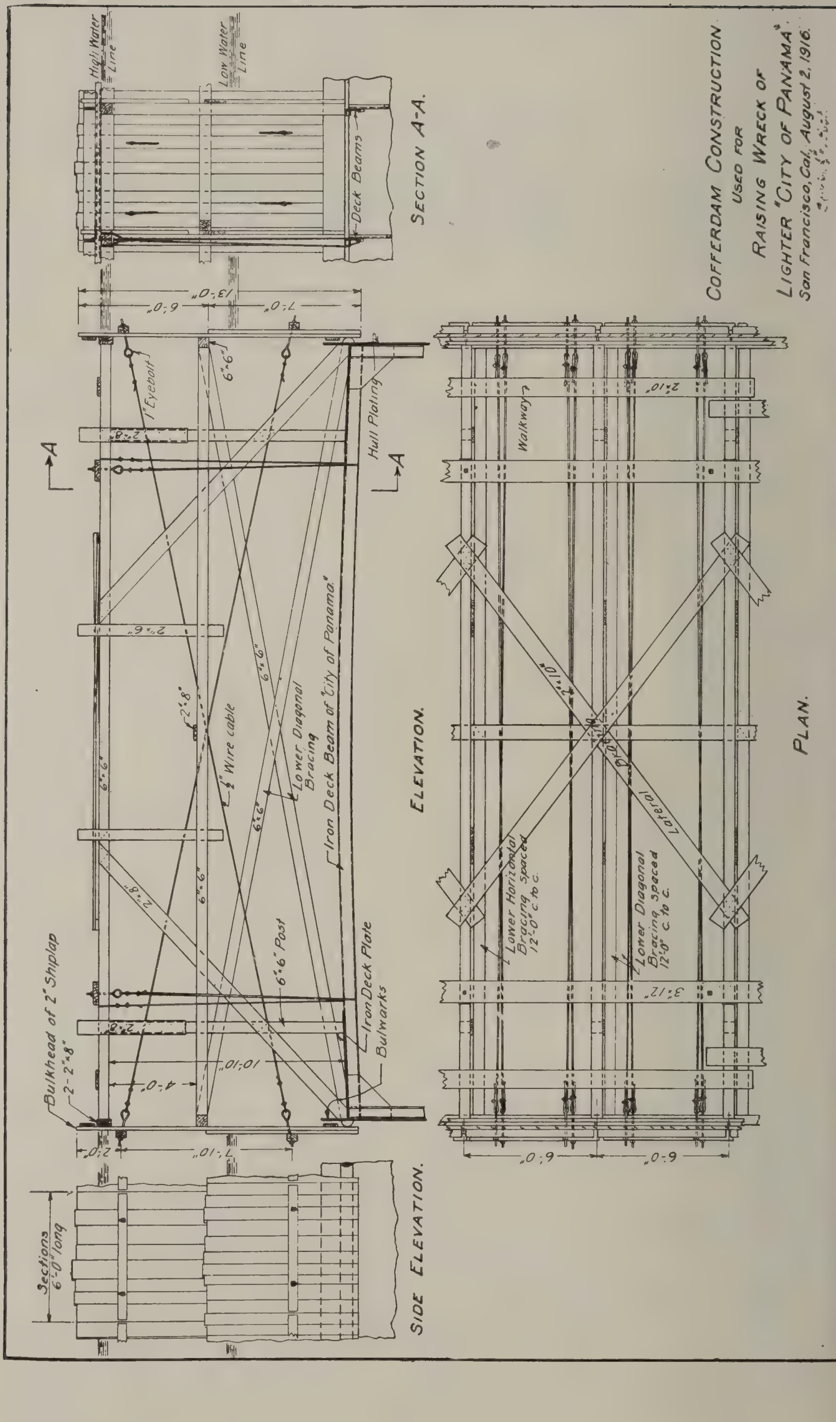
BY

Mr. H. L. DEMERITT,
Assistant Engineer.

The ship was formerly a freight and passenger steamer and sailed for many years between San Francisco and Panama. It is an iron vessel, built at Chester, Pa., in 1873. Its dimensions are: length, 250 feet; breadth, 36 feet; depth of hold, 20.2 feet; gross tonnage, 1,490; net tonnage, 1,046.

In 1914, on account of the ship's age and the erosion of its plates, it was condemned as a passenger steamer and sold. The buyers removed all of the machinery from the hull, all of the upper works down to the main deck, and all of the main deck to within 5 feet of the bulwarks on each side, except the deck beams, and about 20 feet of the deck forward and the poop deck over this main deck. These decks were left for a capstan above and a donkey boiler between decks. The two masts of the ship were left standing. The deck beams were 6 feet centers except at the two main hatches, which were about 20 by 20 feet.

Thus remodeled, the vessel was to be used as a coal lighter; the coal to be dredged out with a clam-shell or orange-peel bucket through the hatches or between the deck beams. In February, 1915, the hull was loaded with about 1,600 tons of coal and anchored on the flats just south of the city of San Francisco in 22 feet of water at low tide. This locality is exposed to southeast storms. While the ship was anchored there, a violent southeast storm occurred and waves broke over the bulwarks, filling the hold with water, so that it sank to the bottom with about 6 feet of water over the bulwarks at low tide. The bottom of the bay at that place was perfectly level and composed of stiff marsh mud. The ship settled in the mud about 6 feet in a short time, but there was no further settlement afterwards.



COFFERDAM CONSTRUCTION
USED FOR
RAISING WRECK OF
LIGHTER "CITY OF PANAMA".
San Francisco, Cal. August 2, 1916.
SECTION A-A.
High Water Line
Low Water Line
Deck Beams
ELEVATION.
1" Eyebolt
Hull Plating
½" Wire cable
Lower Diagonal Bracing
Iron Deck Beam of "City of Panama."
6"×6" Post
Iron Deck Plate
Bulwarks
Bulkhead of 2" Shiplap
2-2"×8"
13'-0"
6'-0"
7'-0"
10'-10"
4'-0"
2'-0"
7'-10"
PLAN.
Walkway
Lateral
Lower Horizontal Bracing spaced 12'-0" c. to c.
Lower Diagonal Bracing spaced 12'-0" c. to c.
SIDE ELEVATION.
Sections 6'-0" long

The owners employed a barge with a boom and bucket and removed the greater part of the coal first, and then endeavored to raise the hull bodily with the tide by placing a barge on each side with heavy I-beams across the hull from one barge to the other. Three heavy chains were passed under the hull and hauled taut at low water. A large wrecking boat was anchored about 1,500 feet inshore in shoal water. A heavy cable was made fast to the wreck, with the intention of hauling it into shoaler water at high tide by power from the wrecking boat. The floating barges along-

Removing of Wreck, *City of Panama*. Interior view of cofferdam, showing side walls and the method employed to fasten the wire rope ties to them. A waling piece was carried along the outside of the cofferdam in way of the eye-bolts.

side the wreck did not have floating capacity enough to raise it, and the I-beams were also too weak. After several weeks of ineffectual effort to move it, the wreck was abandoned by the owners and the Government was notified of that fact.

In December, 1915, the District Engineer Officer, First San Francisco District, advertised for bids for removing the wreck. The specifications gave the contractor the privilege of removing it as a whole or cutting it up and removing it in pieces, the con-

tractor to have all salvage from the wreck. On January 20, 1916, bids were received for the work, as follows:

San Francisco Bridge Co.	$19,800
Martin Lund	13,400
Chas. Johnston	12,845
Whitelaw Wrecking Co.	11,400
Melvin O. Taylor	9,280

The lowest bidder was awarded the contract.

There was considerable speculation among the contractors as to whether the chains used under the hull in the attempt to raise it had cut through the plates, leaving holes that would have to be patched if the wreck were raised as a whole.

The successful bidder decided to put a bulkhead around the wreck against the bulwarks, on the grounds that if he were unsuccessful in floating the wreck as a whole he could cut it up with high explosives and sell the old iron of the hull for scrap. His first plan, submitted to the District Engineer Officer for approval, was to drive a row of piles around and close to the wreck to hang his bulkhead on until it was completed and the wreck ready to pump out, and after the water was lowered some on the inside, so as to give a pressure on the bulkhead, it would be released from the piles, but this plan was soon abandoned. He then proceeded to build an open platform over the whole wreck, putting in 6 by 6 inch cross braces, against which he made his bulkhead fast. Posts, 6 by 6 inches, were set up on the deck near the bulwarks, and the 6 by 6 inch braces were put across the top of these posts, which were in turn tied down by ½-inch wire cables passed under the deck beams and up to the deck of the platform, where there was an eye-bolt and nut to take up the slack. The bents were 6 feet centers and well braced diagonally and horizontally. Planks were placed on top for convenience of handling and placing the bulkhead. The bulkhead was contsructed in sections, about 6 feet wide and about 13 feet long, for the portions amidship. Toward each end the sections were made shorter. The bulkhead was constructed of 2 by 8 inch ship-lap lumber, double thickness, the work being done on a barge alongside.

The sections of bulkhead were made and put up in pairs, one on each side of the wreck. Two wire cables were first made fast near the bottom of each section before it was put up and the free ends of the cables made fast, as it was put in place, near the top of the corresponding section on the opposite side of the wreck. The

cables were made taut by means of an eye-bolt with a nut on the outside. When the sections were first put up they were hung on a waling along the edge of the platform until the wire cables could be made fast and hauled taut. One and, sometimes, two sections were put up per day on each side of the wreck with a gang of 7 men. A 6 by 6 inch brace was put up at every other section from the lower waling on the section to the bulwarks on the opposite side, and every other section had a 6 by 6 inch horizontal brace from lower waling to the opposite section. At the stern of the wreck the sections were made to conform to the curve of the

Removing Wreck of *City of Panama*. Showing part of completed bulkhead and platform.

hull, and the cables and braces were made fast to the platform. The bulkhead extended about 1 foot above high water and was strong enough to withstand the heavy currents that passed the wreck.

After the bulkhead was completed one 8-inch and two 10-inch centrifugal pumps were placed on the deck near the bow and one 30-horsepower engine was set up to run the pumps. Steam was furnished to this engine by a tugboat lying alongside. On the first attempt to pump the water out it could be lowered only 15 inches, on account of scupper holes in the sides of the wreck. A

diver was sent down, and he plugged these holes with sacks of concrete. The pumps were again started, and the water was lowered about 5 feet when the stern of the wreck began to rise. It was estimated that there was about 250 tons of water to 1 foot in depth of the wreck, so that about 1,250 tons of water was removed when the wreck began to rise at the stern. The stern rose about 12 feet before the bow started. There was no suction between the bottom of the wreck and the mud. After the bow had risen about 5 feet, tugs towed the wreck on to the mud flats, where the bottom of the bulkhead was above high water.

The bow of the wreck was slow in coming up, on account of the machinery being forward and a quantity of coal being under the deck there also.

No holes were found in the bottom of the ship caused by the attempt to lift it bodily. The cost to the contractor, up to the time it was put on the mud flats, was about $4,000.

Notes on the United States Dredge "Barnard."

BY

Mr. J. R. PEYTON,
Junior Engineer.

The steel twin-screw dredge *Barnard* was built in 1904 to assist in deepening the Southwest Pass of the Mississippi River. The vessel is a product of the New York Shipbuilding Co., Camden, N. J., and the original cost was $240,000.00.

The general dimensions are: Length, 198 feet; beam, 38 feet; depth, 14 feet; draft, 9 feet; displacement, 1,300 tons. The propelling engine room is at the stern, the pumping engine room forward with the boiler room between.

As originally built, there was a well on the center line of the hull 7 feet wide, beginning 28 feet from the bow and extending aft 60 feet. At the forward end of this well a drag-arm rested on trunnions with a drag-head at the lower end. The suction pipe on the *Barnard* was led through a swiveling joint in the trunnion to a double suction 36-inch centrifugal pump, driven by a vertical inverted triple-expansion engine having cylinders 21 inches, 32 inches, and 54 inches, with a common stroke of 26 inches. The discharge pipe led to either side and to the stern. A large jet pump was provided to agitate the material.

The method used in dredging with the *Barnard* was to cruise up and down the channel to be dredged, towing the ponton discharge pipe line at the stern, it being held across the channel in a long curve from the dredge by a baffle-plate at the discharge end of the pipe line, which held this end of the line approximately transverse to the channel by the force of the discharge impinging on the baffle-plate. When dredging in a channel exposed to the action of swift currents or high winds, the end of the pipe line was sometimes towed by a tugboat. The *Barnard* did some very good work in the Passes at the mouth of the Mississippi River in deepening and

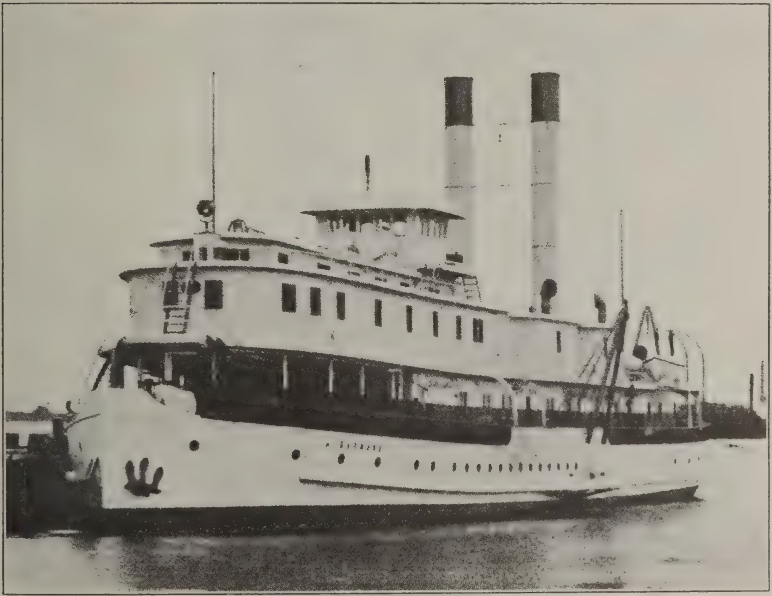


Fig. 1. The *Barnard,* as Originally Constructed.

widening the channels to the necessary depth to operate with seagoing dredges.

When the channels in the Passes were thus deepened and widened it became cheaper to operate with seagoing dredges, and the *Barnard* was transferred to the Mobile District for work at Gulfport. From there the dredge was transferred to Havana to assist in the raising of the battleship *Maine.* After the operations in raising the *Maine* were successfully concluded, the *Barnard* returned to Mobile and was disposed of to the Jacksonville, Fla., District at a transfer cost of $25,000.00.

Fig. 2. The *Barnard* at Work. Hillsboro Bay, Florida, 1915.

The districts bordering on the Gulf Coast were supplied with the ordinary type of pipe-line hydraulic dredges and had no use for the *Barnard*. The Jacksonville District was, however, in need of a hydraulic pipe-line dredge of large capacity and, as the *Barnard* could be altered to an efficient hydraulic pipe-line dredge by changing the engines and pump and fitting spuds and a cutter ladder at a less cost than purchasing a new dredge outright, it was decided that, as the hull of the *Barnard* was in good condition, the system of dredging should be changed on the dredge. Designs for the alterations to the *Barnard* were prepared in the Office of the Chief of Engineers in accordance with the above decision.

Fig. 3. The Reconstructed *Barnard*. Hillsboro Bay, Florida, 1915.

The reconstruction was done at the Navy Yard, Charleston, S. C., in 1914, at a cost of $128,000.00. The old double-suction pumping installation was replaced by a 22-inch single-suction steel pump, directly connected to a triple-expansion engine. The new pump, while considerably smaller, can pass a solid nearly as large as the old one, the single-suction pump being the type usually adopted for dredging. The center well was extended to the bow and the after end was closed for a distance of 29 feet. The combined pilot house and operating room was moved forward.

A 65-ton cutter ladder was placed on trunnions at the after end of the well. The engine for turning the cutter is located on the ladder over the trunnions. The cutter for soft material is of

the spiral type, as seen in Fig. 3, while for rock work a cutter with inserted teeth, shown in Fig. 4, is used. The former is revolved at about 12 revolutions per minute and the latter about twice as fast.

A ball-and-socket joint makes the flexible connection in the suction pipe between the ladder and the hull. The dredge can dig to a depth of 35 feet below the surface and make a cut 300 feet wide on one advance. The spud anchors are 33 inches in diameter and 60 feet long. Oregon fir and gum have been used,

Fig. 4. Type of Cutter Used for Rock Work.

the latter proving more satisfactory—due to the fact that the gum is more flexible and also tougher. The spud wells are located inboard and outboard of the propeller shafts. The spud gallows frame extends 36 feet above the deck.

The winding machinery used to swing the dredge across the cut, and hoist the spuds and ladder, is located on the main deck forward of the pump room. The ratio of the gearing of the swinging drums is such that the dredge moves slower when swinging to the right, this being when the cutter blades are rising and

engaging the material and thus encountering greater resistance. Little material is expected on the back swing.

A system of hydraulic control to the winding machinery was installed, a uniform pressure of about 60 pounds per square inch being maintained. Fresh water is used. The hydraulic cylinders are proportioned to produce about 750 pounds piston thrust to operate the frictions and brakes. This installation has proved satisfactory service, the only disadvantage being that the brakes can not be gradually adjusted.

There is a complete machine shop and the usual auxiliaries, including ice plant, air compressor and evaporator. It is of interest to note that there are two auxiliary pumps in service which were recovered from the battleship *Maine*. The crew is composed of about fifty men.

Upon the completion of the rebuilding, a series of nozzle tests were conducted. The angle of cone of all nozzles was 15 degrees, and their lengths being made equivalent to various lengths of discharge pipe. Fig. 5[1] shows a nozzle equivalent to 5,100 feet of 22-inch discharge pipe. The discharge pressure was 38 pounds per square inch, as determined by a gauge at the nozzle, the pumping engine developing about 575 horsepower. An efficiency of about 44 per cent was obtained.

The discharge pipe line is equipped with the Parker mechanical joint. This device is fashioned after the ball-and-socket joint, but it is not entirely satisfactory, due to the fact that it is not sufficiently flexible in rough water. In quiet water it is superior to the rubber sleeve.

The *Barnard* is now one of the few self-propelling seagoing dredges of this type. This feature is of advantage especially when a sea voyage is necessary for docking purposes, as is the case at her present station.

Since being rebuilt, the dredge has been engaged on the improvement of Tampa Harbor, Florida, and her performance there has demonstrated the practicability of the alterations in the dredging system.

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[1]Not printed.

Whitewash as a Rust Preventive.

BY

Mr. M. Meigs,
U. S. Civil Engineer.

The writer of this paper has been making some experiments with lime as a protection of steel against rust, the suggestion having come from seeing a groom deposit burnished steel bits in lime water to "keep them from rusting."

The experiment consisted of preparing two pieces of structural angle iron by sand-blasting all the faces except one of each piece, and in addition polishing one face, then immersing them in fresh Mississippi River water; the Mason jar containing one of the pieces having, in addition to the water, slaked lime to a depth of ½ inch. The steel was left immersed in the water for fourteen months.

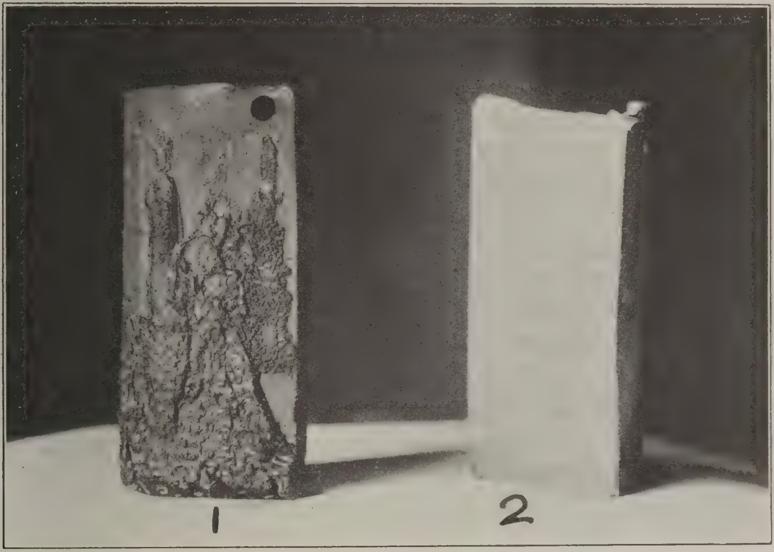
On the 8th of December, 1916, the steel immersed in the raw water was found to be thickly corroded; not only was the steel itself covered with rust, but a considerable collection of rust had flaked off and fallen to the bottom. A sort of mantle of rust covered most of the metal. The piece immersed in the jar with the lime was absolutely unaffected. Not only was there no rust, but the polish on the polished face was as perfect as when the piece of steel was first put in the water.

The above experiment suggests that, where it can be used, lime forms an excellent and very cheap rust preventive. It is applicable, for instance, to the interior of double bottom structures, such as ballast tanks in steel gates, the interior of steel hulls, and the like places where the whitewash is not liable to be washed off, and where the air is always damp and the walls sweaty.

In the steel gates of the Keokuk Lock, which, as is well known, are very large, this method is being applied in the submerged air tanks which support a part of the weight of the gates. It seems to stick to the walls indefinitely, and positively arrests the rusting action which takes place where these tanks naturally sweat and are continually damp. In fact, the sweating helps the whitewash to adhere. The whitewash applied months ago to these gates is in perfect condition and the air in the tanks is noticeably sweet

and no rusting can be found. On the bottom of these tanks, where more or less water continually stands, as there is slight leakage, it is sufficient to distribute the lime in the various pockets and replace it from time to time, as the water is occasionally pumped out. There is usually 2 or 3 inches depth of water on the bottoms of these tanks, but as long as this water is kept strongly alkaline by free lime it does no harm. Apparently, the lime being alkaline neutralizes the acidity of the river water and prevents it from becoming an electrolyte, electrolytic corrosion of steel being the generally accepted theory at the present time.

It is found in applying this whitewash in these confined spaces



that the lime acts as a strong irritant to the skin of the painters. Their lips, faces, and hands are affected and some form of helmet with air circulation would lessen their discomfort and the possible danger to their health.

Their are two methods of preserving steel at present in use:

(*a*) One of these is to cover the steel with an absolutely watertight covering such as the patented "Bitumastic" process, much used but also very expensive. (The Bitumastic solution and enamel cost, applied, 14 cents per square foot in the case of the interior of one of the lock gates at Keokuk, and this did not include the cost of scraping and cleaning.)

(*b*) The second is to use an "inhibitive" paint which, by reverse electric tension, seems to hinder the electrolytic decompo-

sition of the metal. Red lead is the foremost of these "inhibitive" paints.

(*c*) Neutralizing the acid in the water by means of lime might be considered a third method. A paint called by the makers "Tockolith" is claimed to act in this manner.

The cost of whitewashing is nominal, however, in comparison with any paint. It is even doubtful whether any cleaning would be necessary with whitewash, as the dampness would carry the lime solution into the rust and put a stop to the corrosion. If some vehicle could be contrived which, mixed with lime, would adhere to the steel under water, this process might become valuable for the outside of submerged steel structures.

It might be used to prevent the pitting and corrosion of steel pipes buried in the ground. All that would be necessary would be to sprinkle lime about the pipe before covering it up. It would neutralize the acid in the soil and thus prevent electrolysis.

It is very easy to try this experiment with a couple of glass jars filled with water, and it is suggested that anyone interested may try it for himself.

An illustration is printed showing the condition of the two specimens of steel after fourteen months of submersion. Specimen No. 1 is the steel which was acted on by the raw water. The illustration does not give all the rust that showed on this piece, as much of it fell off in removing the specimen from the jar. There was also a flocculent mass of rust collected on the bottom of the jar. All of this rust was collected on a filter paper, dried and weighed, with the following result:

Specimen No. 1.

	Grams.
Original weight of specimen	328.72
Weight of oxide Fe_2O_3	11.03
Weight of metal lost	7.72
Per cent of metal lost	2.35

Specimen No. 2.

Original weight of specimen	300.00
Weight of oxide	0.00
Weight of metal lost	0.00
Per cent of metal lost	0.00

PROFESSIONAL MEMOIRS

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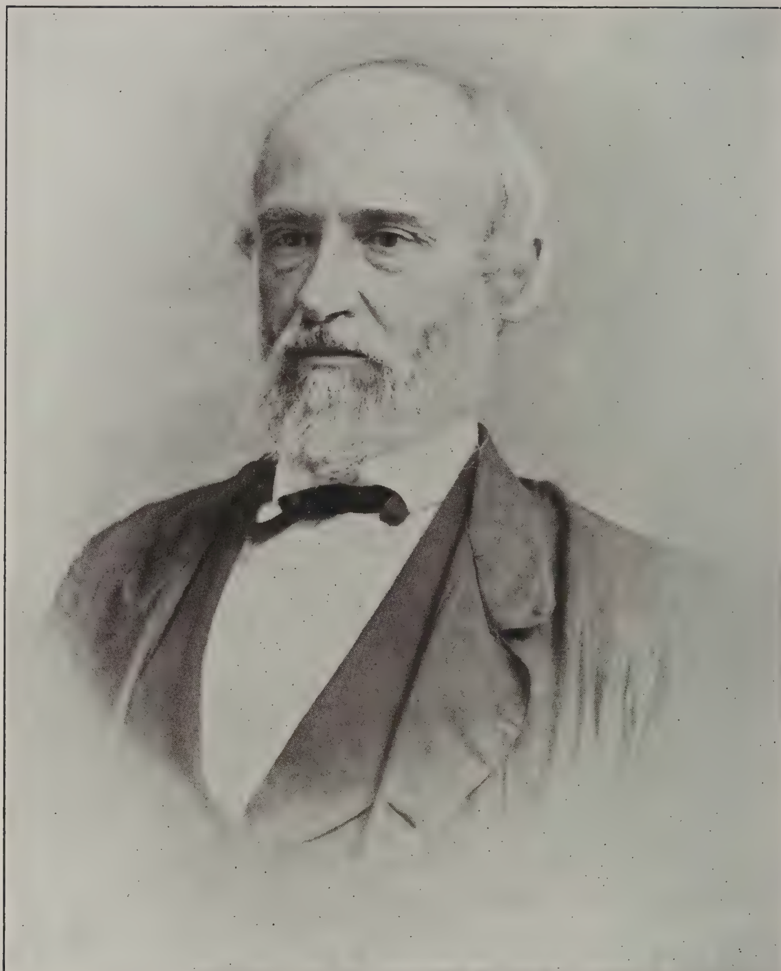


JOHN D. KURTZ.
Born, 1819.
Cadet, U. S. M. A., 1838-1842.
Second Lieutenant, Corps of Engineers, 1842.
First Lieutenant, Corps of Engineers, 1853.
Captain, Corps of Engineers, 1856.
Major, Corps of Engineers, 1863.
Brevet Colonel, U. S. Army, 1865.
Lieutenant Colonel, Corps of Engineers, 1866.
Died, 1877.

Improving the Ohio River below Pittsburgh, Pa.

WIDENING THE LOUISVILLE AND PORTLAND CANAL AT LOUISVILLE, KY.

BY

Maj. J. C. OAKES,
Corps of Engineers; M. Am. Soc. C. E.

Neglecting interference with navigation due to the lack of water at extreme low stages, the Ohio River is navigable throughout its entire length, except for about 2 miles opposite Louisville, known as the Falls of the Ohio. The obstruction at this point is formed by an irregular mass of limestone underlying the entire width of the river. This rock forms a natural dam, creating a deep pool above and a fall at low water stages of about 27 feet from head to foot of the falls. Navigation in the open river over the falls is impossible, except at stages of about 29 feet and upward, measured on the lower gauge.

In the original condition of the river, it was therefore impossible for boats to pass Louisville during about ten months of the year. To correct this condition, and to provide for navigation at all times, the Louisville and Portland Canal, with locks at the lower end, was constructed around the falls. A canal with three locks was first completed in 1830. Later, the canal was widened and the three small locks were replaced by two larger locks. The improved canal and new locks were completed and opened in 1872. For the purpose of increasing the depth of water in the canal to 9 feet at pool stage, a dam was built across the head of the falls.[1]

Before beginning this work the canal was 86½ feet wide, and

[1]For full description of the situation at Louisville and of the successive works of improvement, reference is made to the Reports of Chief of Engineers and to PROFESSIONAL MEMOIRS, Corps of Engineers, U. S. Army (Vol. 6, No 29), ''Works at the Falls of the Ohio River, Louisville, Ky.,'' by Maj. J. C. Oakes. In this latter work a complete historical sketch of the works of improvement is given, with description of the works being carried on at present time, and details of design, etc.

the two locks at the lower end of the canal are 80 feet wide. In order to provide the same navigable capacity at this point as at other locks in the Ohio River, it was decided to replace the two locks by a single lock 600 feet long by 110 feet wide, and to increase the width of the canal to 200 feet.

This report relates only to the work of increasing the width of the canal, which is indicated in black on the north side of the canal on Plate I. The following details were furnished by the U. S. Inspector in Charge, Junior Engineer Robert A. Strecker.

The work was advertised February 25; bids were opened February 26, and contract let to the low bidder—the Henry Bickel Company, of Louisville, Ky., on May 7, 1913. The amount of the contract, based on the estimated quantities, is $656,094.60. For a summary of bids see Table I. The following report describes the several operations, methods employed, and work done on this contract from its beginning, to January 1, 1916, when the work was 91 per cent completed. Briefly, the contract covers the following work: the excavation of the Louisville and Portland Canal to a width of 200 feet; the construction, north of the canal, of an embankment 30 feet high, with macadam roadway thereon; the removal of the existing north canal stone wall; the construction of a new concrete wall, a concrete pier and abutment for the new lift bridge, and concrete foundations for the section of the emergency dam between the old and new canal walls; the extension of the dry dock culvert through the old locks (the ones first constructed in 1828-1830) for unwatering the dry dock; the construction of a concrete retaining wall across the upper end of these old locks, and the filling of these lock chambers and adjacent ground to increase the available area of the United States reservation at the west end of the canal. The approximate quantities, with unit prices, are shown in Table I.

The canal was limited by vertical masonry walls; the bottom of the canal slopes slightly towards the locks, varying from elevation 403[1] at head to 400 at foot of canal; water surface (pool level) is at 412. The old canal walls are of cut stone masonry, resting on the natural rock ledge. The canal was excavated through this rock, which had a general elevation at the head of the canal of approximately 412, with slight inclination towards the west until, at the foot of the canal, the surface of the rock was at elevation 403.

[1]All elevations are referred to Sandy Hook datum.

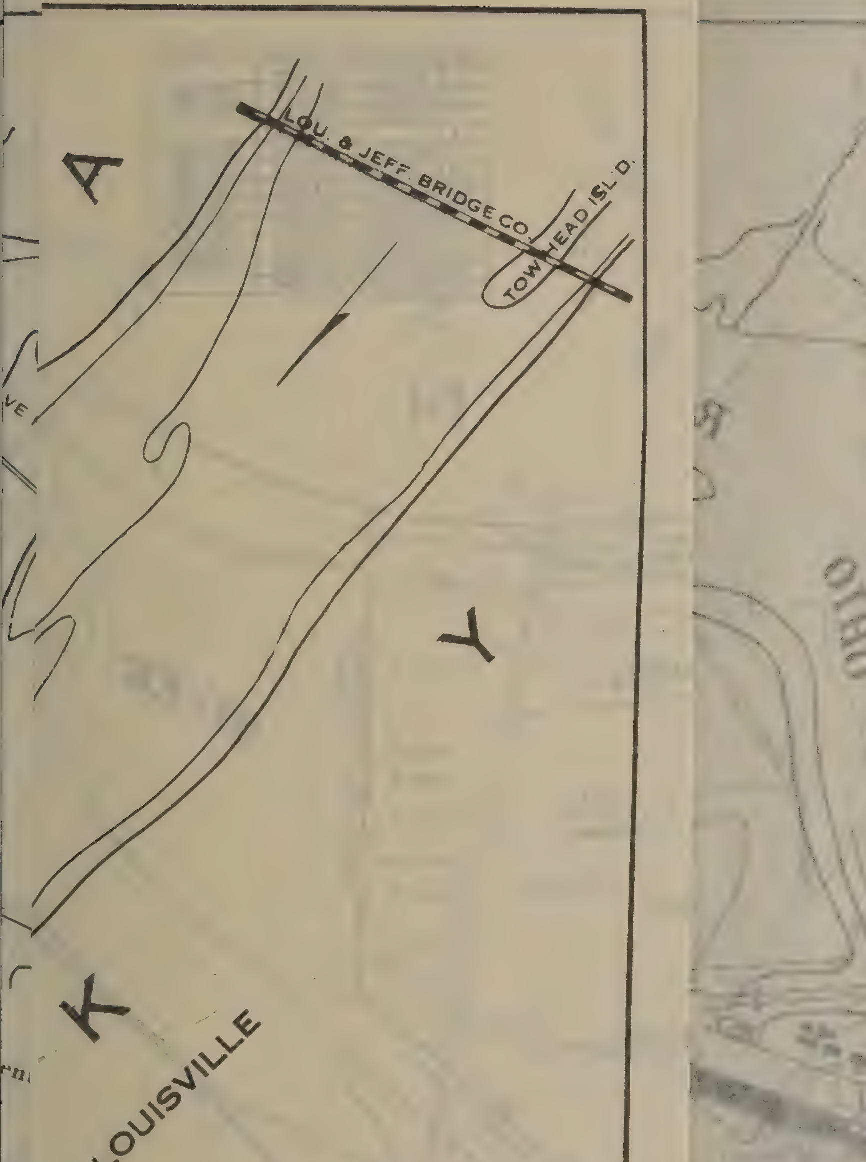


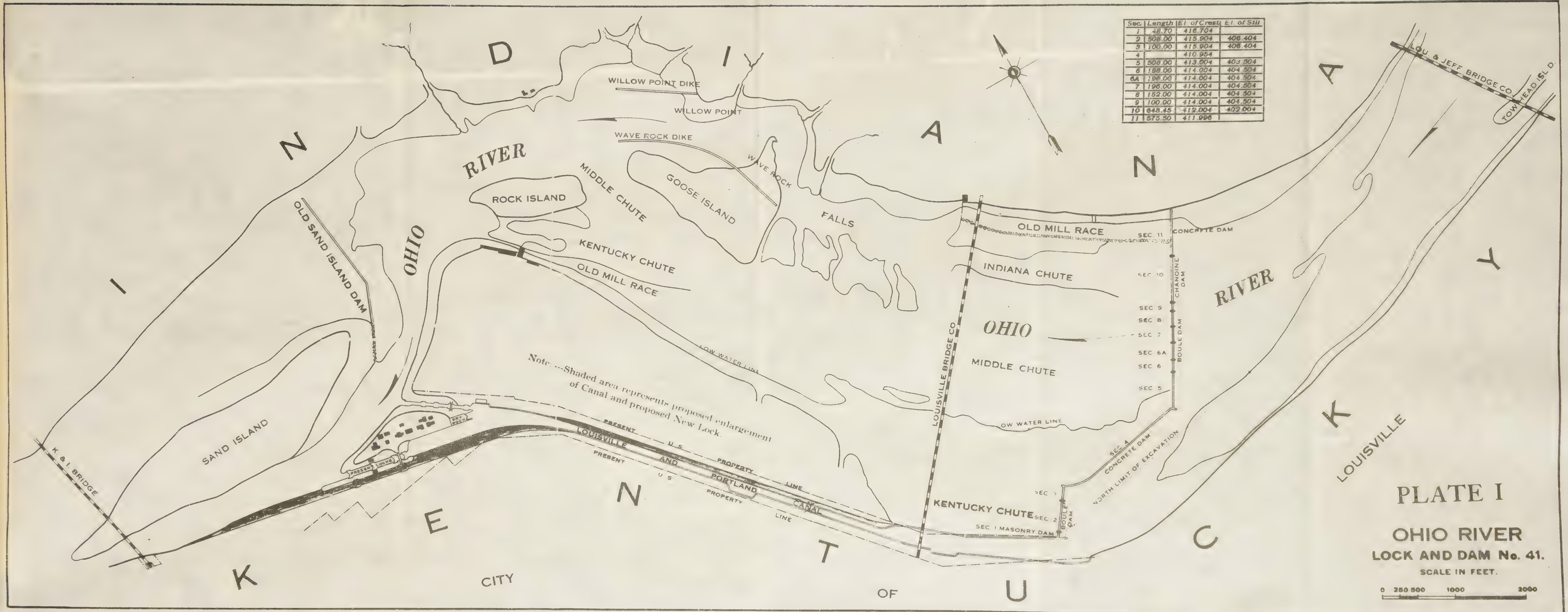
PLATE I

OHIO RIVER

LOCK AND DAM No. 41.

SCALE IN FEET.

0 250 500 1000 2000



Sec.	Length	El. of Crest	El. of Sill
1	48.70	416.704	
2	508.00	415.904	406.404
3	100.00	415.904	406.404
4		410.954	
5	508.00	413.004	403.504
6	188.00	414.004	404.504
6A	196.00	414.004	404.504
7	196.00	414.004	404.504
8	152.00	414.004	404.504
9	100.00	414.004	404.504
10	648.45	412.004	402.004
11	575.50	411.996	

PLATE I

OHIO RIVER

LOCK AND DAM No. 41.

TABLE I. *Abstract of Proposals for "Widening Louisville and Portland Canal" at Louisville, Ky., Opened March 26, 1913.*

Items.	Quantities.	No. 1. Henry Bickel Company. Louisville, Ky.		No. 2. J. H. Cahill. Louisville, Ky.		No. 3. The Callahan Construction Co. Knoxville, Tenn.		No. 4. Mason & Hanger Co. Richmond, Ky.		No. 5. Asheville Construction Co. Asheville, N. C.	
		Unit Prices.	Totals.	Unit Prices.	Totals.	Unit Prices.	Totals.	Unit Prices.	Totals.	Unit Prices.	Totals.
Common excavation	770,000 cubic yards	$0.45	$346,500.00	$0.45	$346,500.00	$0.50	$385,000.00	$0.45	$346,500.00	$0.40	$308,000.00
Rock excavation	205,000 cubic yards	.90	184,500.00	.95	194,750.00	.80	164,000.00	1.10	225,500.00	1.25	256,250.00
Drilling bolt holes	550 linear feet	1.00	550.00	.25	137.50	.50	275.00	.80	440.00	.60	330.00
Stone paving	24 cubic yards	3.00	72.00	10.00	240.00	7.00	168.00	7.00	168.00	4.50	108.00
Reinforced concrete	490 cubic yards	20.00	9,800.00	7.00	3,430.00	10.00	4,900.00	12.00	5,880.00	11.00	5,390.00
Plain concrete	16,951 cubic yards	5.00	84,755.00	5.50	93,230.50	6.50	110,181.50	5.75	97,468.25	7.40	125,437.40
Channeling	48,300 square feet	.30	14,490.00	.30	14,490.00	.40	19,320.00	.40	19,320.00	.38	18,354.00
24-inch cast iron culvert	385 linear feet	8.00	3,080.00	5.00	1,925.00	4.00	1,540.00	8.00	3,080.00	7.00	2,695.00
16-inch cast iron culvert	24 linear feet	6.00	144.00	3.00	72.00	2.50	60.00	4.50	108.00	4.00	96.00
Reinforcing rods	58,000 pounds	.05	2,900.00	.05	2,900.00	.04	2,320.00	.04	2,320.00	.075	4,350.00
Iron check posts	1,536 pounds	.10	153.60	.07	107.52	.10	153.60	.08	122.88	.09	138.24
Macadam roadway	12,200 square yards	.75	9,150.00	1.25	15,250.00	1.00	12,200.00	1.00	12,200.00	1.80	21,960.00
Total of bid	----------	-----	$656,094.60	-----	$673,032.52	-----	$700,118.10	-----	$713,107.13	-----	$743,108.64

surface between the old and new walls east of the 18th street bridge. Later, after clearance under that bridge had been provided, this machine, in conjunction with the Marion steam shovel, excavated the material remaining in place west of 18th street bridge. This excavated material was hauled by locomotives and cars to the trestle dump at the eastern end of the work and dumped as fill for the new embankment. The approach to this trestle was effected by a 3 per cent incline; with this grade a train consisting of one locomotive and four cars was able to ascend the incline without any difficulty. The Thew steam shovels, which, as previously noted, were the first machines to begin operations, excavated along the old embankment and loaded material into dump wagons which were hauled to the new embankment and dumped. The lower 10 feet of the new embankment was constructed in this manner.

The contract specified that the contractor should maintain communication between the 18th street bridge and the new embankment for foot passengers and wagon traffic. For this reason it was deemed advisable to operate the excavating plant in two groups, so as not to disturb the old north bridge approach until the excavation east of the bridge had been accomplished, when the north abutment and bridge approach were replaced by a bridge carried by timber trestle bents resting on the floor of the newly excavated canal. The center line of the trestle bridge was deflected to the east of the center-line of the old approach, in order to allow traffic over the old approach while the new one was being built, and to allow later the construction of a new pier on the old center-line without interfering with the trestle approach. This temporary trestle was designed to carry and maintain traffic at all times and with sufficient overhead clearance for the passage of the contractor's plant underneath.

The extension of the dry dock culvert was completed during the second working season, which made it possible to begin the work of filling the old lock chambers. In order to do this, a track was built connecting the pit with the old locks. This track was placed on the berm of the old canal wall, between 18th street and a point near the lower end of the canal where it crossed to the berm of the new wall upon a prism of earth left in place for that purpose, and extended directly to the old locks by means of a timber incline and the road on top of the old embankment. From the upper end of the locks the main track divided, forming a wye. One branch was built along the northern limits of the depression, sup-

ported by a timber trestle at elevation 450, and the other branch along the southern limits of the depression upon the high ground at elevation 448. As the fill was made to the required grade by dumping from these two branches, the track was shifted by successive moves towards the center of the lock.

In filling the old lock chambers as well as in constructing the new embankment, a vertical shrinkage of 15 per cent was provided for. It is believed that this allowance is somewhat high for ordinary conditions, but in this case, since the first material

Fig. 2. Excavating East of 18th Street Bridge. June 25, 1914. Note concrete backing to rubble masonry wall; also concrete cap.

to be excavated and dumped was mostly earth and the last material excavated was rock, the upper portion of all fills consisted largely of rock. Consequently, it was thought advisable to increase the shrinkage allowance because of this superimposed rock load. It has been determined, by running levels over the fill at intervals ranging from 6 to 18 months, that the allowance of 15 per cent for shrinkage was none too high.

As it is necessary to maintain navigation in the canal throughout the period during which the work is to continue, and as the canal is too narrow to allow the construction of a cofferdam within which

the excavation below pool level may be made, it was decided that the best method of executing the proposed work would be to excavate as much of the material as possible in the dry, using the old wall and a portion of the underlying rock ledge as a cofferdam behind which the work can be carried on, and when everything else shall be completed to remove this cofferdam by blasting and ordinary dredging methods.

The old canal wall was of stone masonry, with a considerable

Fig. 3. Excavation and Wall Construction East of 18th Street Bridge. November 4, 1914.

number of open joints and weep holes, through which much water entered the pit. It was thought at first that, by leaving in place behind the old wall a prism of earth about 15 feet in width, the leakage would be limited to an amount that could be taken care of by the pumping plant without interference with the work. This method of preventing leakage was a failure, since the material left in place was found to be composed of loose rock with a large proportion of voids. This earth backing was then completely removed

to ledge rock, exposing about 1,000 feet of wall, and a small concrete backing, 12 inches wide and 18 inches high, was built on the rock ledge against the rear of the wall (Figs. 2 and 3). The weep holes through the old wall were closed with wooden wedges and the joints above the concrete slab calked with sacks. Although this method decreased the leakage considerably, it proved expensive as well as difficult, owing to the necessity of placing the concrete in water, and it was finally abandoned and the following plan adopted, which has proven to be effective as well as economical. The minor leaks through the wall were stopped by causing a mixture of fine cinders, sawdust and manure to be drawn into the open joints from the canal side of the wall. This material was placed in a small wooden box with one side open and the bottom perforated. The open side of the box was held against the canal side of the wall, causing the water to flow through the perforations and carry the mixture into the open joints. The depth to which the box was submerged was determined by locating the inflow of water from the rear of the wall. A foreman and six men were detailed to attend to this work. The success attained in preventing leakage by this method was such that during ordinary river stages one 12-inch centrifugal pump kept the pit unwatered.

Before blasting the rock immediately behind the old masonry wall, a channelled cut was made to grade from 8 to 12 feet back of the face of the wall. The masonry wall, together with the supporting rock ledge thus channelled, served as a cofferdam. When the steam shovel removed the material against the channelled face of this ledge, in addition to the method described above for preventing leakage through the masonry wall, it became necessary at many points to drive wooden wedges in the joints of both wall and ledge. These wedges were driven from the pit side.

The rock to be excavated belongs to the Devonian limestones. In general, the rock encountered consisted of one stratum, from 3 to 6 feet thick, of gray corniferous limestone, very hard, and in places almost like flint, and several thinner underlying strata of much softer magnesian limestone or cement rock.

The rock surface along the site of the new concrete wall was first exposed by the first dragline excavator at the upper end of the work. For this reason, the first channelling was done at that end. Another reason for beginning channelling at that end is that the general dip of the rock surface is towards the southwest, and, other factors being equal, channelling is less difficult in the

direction of drainage. Actually, however, the channelling at that end was the most difficult, because of maximum depths of cut and thickness of the limestone. At first it was planned to use one Ingersoll-Rand channelling machine to make the complete cut, but owing to the toughness of the overlying stratum, the progress made with this machine was unsatisfactory. In order to avoid continued trouble from dull bits, it was necessary to use Black Diamond drill steel of maximum hardness. Finally, the usual channelling tool, consisting of five 1-inch steel pieces, was discarded for a three-piece tool of 1⅛-inch steel. This change helped matters, but still progress was unsatisfactory. It soon became evident that one channelling machine, even when working two shifts per day, could not make sufficient progress, as it was necessary to channel on both sides of the pit—on the canal side to prevent the disruption by blasting of the ledge rock acting as a cofferdam, and on the other side to provide a vertical face for the rock to be left as part of the vertical canal wall. For this reason an additional and more powerful machine, a Sullivan Duplex, was purchased. This machine, having two independent sets of cutting tools as well as a mechanical device for regulating the number and length of strokes, was not only able to channel faster, but by reason of increased metal area of steel bits, was also better adapted to the rock encountered. By the use of a broad heavy steel bit for the first 6 inches of cut, this machine was able to obtain much better alignment. The Sullivan machine, as a rule, completed the cut through the corniferous limestone only and was then followed by the Ingersoll-Rand machine, which completed the cut to grade through the softer cement rock.

The plans show the the concrete wall resting directly on the rock ledge with a channelled keyway to prevent the concrete wall from sliding on its base. All attempts to channel this keyway were unsuccessful, as the impact of the bit on the rock invariably caused the rock to break along horizontal seams between the face of the rock and the keyway. Attempts were then made to form the keyway trench by means of closely placed drill holes, charged and exploded with small quantities of dynamite. These attempts were also unsuccessful. By approval of the District Officer there was substituted for the keyway trench 1-inch twisted bars, 8 feet long, spaced 3 feet 6 inches center to center, and grouted 3 feet into the rock foundation. In order to resist movement of the wall by tension of the rods as well as shearing, the holes for the anchor

rods were inclined towards the face of the wall at an angle of 30 degrees (Fig. 4).

For breaking up the rock to be excavated, the selection of a drilling machine, size and spacing of holes, and the quantity of dynamite charge, were decided by experiments and the experience gained in excavating for the lock at the foot of the canal by the Ohio River Contract Company. Because of the success attained by that company with an Ingersoll-Rand wagon drill, it was decided to begin drilling operations with that type of machine. The

Fig. 4. Channeled Surface, and Preparation of Foundation Bed for Concrete Wall. Driving holes for anchor rods.

advantages claimed for this machine are: its ability to use drill steel 15 feet long in leads mounted on a swinging carriage, ease with which several holes in different lines can be drilled from one position of the machine—owing to its being equipped with a revolving platform—the low steam loss by having the boiler carried on the fixed end of the carriage, and its portability, the whole being mounted on wheels of wide gauge. The large size of drill bit (diameter 3½ inches) used by this machine resulted in too great a concentration of the blasting charge which, when exploded, dis-

rupted the rock into pieces too large for the dipper of the steam shovel.

This trouble became so great that it was finally decided to discard the wagon drill, after the Sullivan Machinery Company had made successful tests at the site with their tripod drills. As a result of the tests, the wagon drill was replaced by five Sullivan tripod machines, equipped with 3⅝-inch cylinders, and hollow steel drills through which steam is forced for cleaning the holes. Each hole was started with a 2-inch drill and smaller drills substituted for each 2 or 3 feet of depth until a 1⅝-inch drill was used to complete the hole. By proper distribution of the charge in these holes, the rock was broken up sufficiently to be handled by the shovel without "dobeing," as the operation of breaking up large rocks is called. Steam for the drills was furnished by a 40-horsepower vertical boiler and a 60-horsepower horizontal boiler, both mounted on a car which could be moved close to the drills. By this arrangement the loss of steam due to condensation in the pipes was reduced to a minimum.

The tripod drills were more economical and more efficient than the wagon drill. Unskilled labor, under the supervision of a foreman, was used for their operation. The maximum number of feet drilled per day with the wagon drill was 225, while the daily output varied from 125 to 130. With five Sullivan machines a maximum of 660 feet per day was drilled, while the daily output was about 400 feet. The first cost of the Sullivan drills was less than that of the wagon drill, but no saving was made because the wagon drill had already been purchased.

The proper spacing for drill holes was determined largely by trial. At first, holes were drilled at corners of 10-foot squares, but later the dimensions of the squares was reduced to 7 feet. Even then, some pieces of the disrupted limestone were too large for the shovel dipper, and an additional hole was drilled at the intersection of the diagonals of each square and sometimes several small air-drilled holes were made through the limestone. These small holes and the holes drilled for anchor bolts were made by small motor-driven compressed air drills.

The amount, distribution and strength of the blasting charge was determined by trial. Experiments were made, using dynamite varying in strength from 40 per cent to 75 per cent, and concentrating the dynamite charge near the bottom of the holes, at top and bottom of holes and uniformly distributing the charge

throughout the holes. The best results were obtained with the holes spaced 7 feet in both directions and with a charge of 75 per cent dynamite concentrated in equal amounts near the top and bottom of holes. The drill holes were carried 18 inches below grade, but in spite of this it was occasionally necessary to redrill the bed rock after blasting. With this method of drilling and charging, the amount of dynamite used, per cubic yard of rock, averaged 0.4 pound. The number of holes exploded at one blast was limited to from ten to fifteen, because of complaints made by

Fig. 5. Excavation Midway of Canal. Loading rock. September 2, 1914.

residents south of and adjacent to the work claiming annoyance, and damage from flying rock fragments.

After the second dragline excavator had exposed the rock surface and the necessary channelling, drilling and blasting had been completed, the removal of the shattered rock was begun. The Marion steam shovel loaded the rock into dump cars made up into trains of four cars each (Figs. 1 and 5). The material was hauled out of the pit and dumped on the embankment or in the old canal lock chambers. Loading these cars with rock, especially the larger pieces, subjected the wooden bodies to conditions of

wear and tear for which the designer of the car had not adequately provided. Moreover, when loaded with wet earth there was difficulty in unloading and it was usually necessary to dig the earth out with shovels. Because of dumping delays, the expensive idle periods of the steam shovel were increased. By the addition of strap iron to the car bodies and galvanized iron plates to the car floors, much more satisfactory results were obtained, the life of the cars was materially increased, and the cars cleaned themselves in dumping.

The pit was kept unwatered by pumps and a drain located at the lower end of the pit connecting with the dry dock culvert and thence with the lower river. This drain was of concrete, about 1,000 feet long, 500 feet of it being built in open trench, and the remaining length in a tunnel. To prevent backwater from lower river entering the pit through this drain, a gate was installed at the pit end of the drain. The pumping plant used in assisting to keep the pit unwatered consisted of three 12-inch Morris centrifugal pumps directly connected to 50-horsepower electric motors, and five steam-driven Nye pumps. The latter, ranging from 3 to 6 inches, were used during the extension of dry dock culvert, and at the upper end of the pit during the early stages of the work. Ordinarily, one 12-inch Morris pump was sufficient for handling the ground and leakage water, and the three pumps were used only after the work had been flooded, due to high water in the canal. Ordinary pool level is at elevation 412, and the top of the cofferdam is at elevation 418. During river floods it is necessary to flood the pit before the pool reaches the top of the cofferdam, and generally the pit was flooded when pool surface reached elevation 414. On several occasions greater depths of water were held out by the coffer, and finally a break in the cofferdam occurred, caused by sliding of the ledge rock on its base[1] (Figs. 6 and 7).

In addition to the masonry wall and rock ledge cofferdam, the construction of a number of small cofferdams has been necessary. After the upper half of the canal widening had been completed, except the removal of the rock cofferdam, the contractor built a coffer across the pit from old wall to new wall and flooded the upper pit to allow the removal of the rock coffer by dredging.

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[1]For description of the accident and an analysis of its causes, see PROFESSIONAL MEMOIRS (Vol. 8, No. 37), "Failure of Masonry and Rock Ledge Cofferdam at Louisville and Portland Canal," by Maj. J. C. Oakes, Corps of Engineers; M. Am. Soc. C. E.

Fig. 6. Excavation Midway of Canal Practically Completed, and Wall Constructed. July 6, 1915.

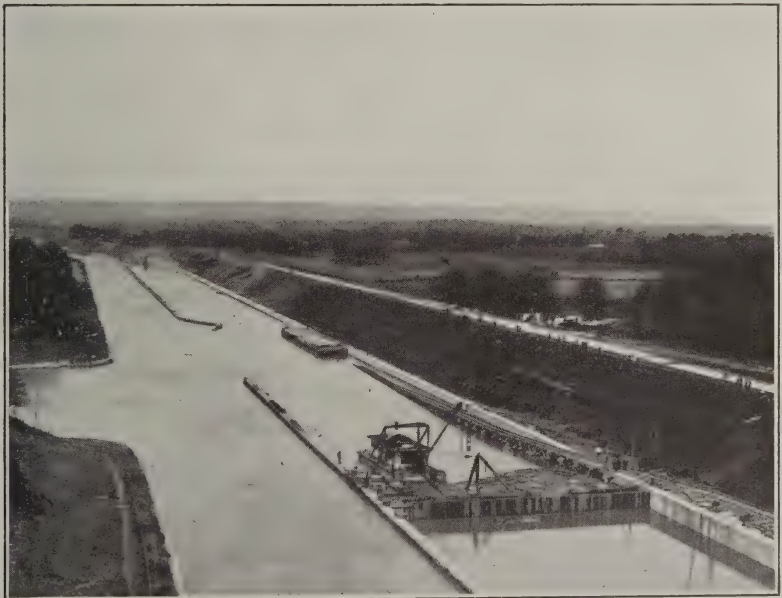

Fig. 7. Break in Wall Coffer Midway of Canal. October 5, 1915.

Originally, the contractor intended to build only one cross coffer, but the accident mentioned above required another cross coffer to be built below the site of the accident. These coffers consisted of two rows of Lackawanna interlocking steel sheet piles 20 feet long, the rows spaced 12 feet apart. The two lines of sheeting were held together by 1-inch rods through each pile near the bottom of the coffer, and through alternate piles near the middle and the top of the coffer. The ends of the dam were forced tightly against the canal walls by wire lines fastened to the top of the sheeting and to anchor bolts in the old wall and to dead men in the new embankment. In cases where the sheeting did not fit tightly against the wall, or the joints opened, wooden wedges were driven into the joints. For filling material, sand and gravel delivered for concrete work were used, and these materials were generally placed in the coffer in alternate layers of about 12-inch thickness, the idea being that the sand would fill all the interstices in the gravel, and it is easier to unload a barge of one kind of material at a time than to attempt to mix the materials. The leakage through this filling at first was considerable, but gradually it decreased with the length of time after construction and became negligible after a short period. Two small coffers were built, one at the juncture of the old and new canal walls and another at the end of the trench for the extension of the dry dock culvert, but neither of these coffers deserves special mention.

The new canal wall is of concrete and was constructed on the bed rock after suitable preparations had been made for the bed of the foundation (Fig. 4). This wall, with a top thickness of 4 feet at elevation 420 and with offset steps at the back, has a width at the base ranging from 6 to 12 feet, depending upon the elevation of the rock foundation. As a rule, the thickness of the base is 50 per cent of the height at any point. Concreting was begun during the summer of 1914, and the wall was constructed in alternate monoliths, each about 40 feet in length. Blaw steel forms were used, except at a few points where special wooden forms were used, as at the new bridge pier, at the junction of the new and old walls, and for the dry dock culvert extension. The wooden forms were built of surfaced plank, tongued and grooved, with a minimum thickness of 1¼ inches, accurately placed so as to form smooth surfaces for the concrete. Tie-rods were supplied with sleeve-nuts near each end, about 2 inches from the concrete faces, and remained in place while the short pieces of rods at ends were taken

out and the holes in the concrete were filled with mortar. Bulkhead forms at the end of sections were provided with 12-inch beveled keys extending vertically from the rock surface to within 12 inches of the wall top. Before placing concrete, the inside faces of all forms were thoroughly coated with paraffin oil.

With the Blaw forms steel is used against concrete surfaces, except that wooden bulkheads and lagging strips were used at points where the rock foundation was found too irregular for a water-tight fit with the steel. These metal forms are constructed as follows: the faces in contact with the concrete at the front and rear of the wall are made up of 2 by 5 foot panels, ⅛ inch thick, connected to angles to resist deformation. Each front panel is held to the corresponding rear one by a ⅝-inch rod. The weight of the face plates, rods, etc., is carried by vertical rods provided with turnbuckles for adjustment, and attached to timber trestle bents spanning the wall transversely. The trestle bents are built of 6 by 8 inch posts and caps, with 2 by 8 inch upper cross-bracing, and are spaced 5 feet center to center. The front columns are fixed in length, and are provided at the bottom with shoes and horizontal axles for 12-inch wheels. The columns at the rear of the form are provided with adjustable shoes and wheels to allow for varying depths of ledge rock. With that exception, the general arrangement for carrying the load at the rear is the same as at the front. The total weight of the form is carried by two rails, one along the channelled face of the wall and the other on the rock ledge at the rear of the wall. The minimum time required for the concrete to set before the removal of forms is forty-eight hours. With three of these forms, it is possible to concrete one section per day under favorable weather and working conditions.

At first, considerable difficulty was experienced in preventing movement of the forms during the placing of the concrete. Although the forms were accurately aligned before beginning work, the tops of the finished blocks were found to be out of line from ⅛ inch to 2 inches. Careful observations were made during the placing of concrete by means of levels and plum-bobs suspended from the forms, and the movement was found to be mainly due to the buoyant or floating effect of the wet concrete in the forms. The unequal trestle column lengths and uplift at the back offsets caused movement towards the pit. This difficulty was overcome by anchoring the forms at 5-foot intervals to the rock foundation with

rods and wire line, and by the addition of braces to the top and bottom of the trestle bents for lateral stiffness. After a form had been used and the concrete had set, the work of moving the form from the completed block to an advanced location was at first slow and tedious. The forms are loosened by unscrewing the turnbuckles behind the plates and releasing the through rods connecting the back and front faces, and then the form is lifted by the turnbuckles attached to the frame, so that the whole weight is carried by the frame on the rollers. A line from a locomotive or locomotive crane is used to pull the form forward on its tracks. At first the change of location was made in a series of short jerky moves with frequent delays for adjustment of the traveler, and unless the pull was steady and properly applied there was danger of breaking the frame. It was found necessary to use skilled labor in moving the forms, as it is necessary to provide careful adjustment of the tracks and accurate application of the tractive force, both in amount, point of application and line of direction. As the men became skilled, the tendency of the form to ''hold up'' during movement was eliminated.

Materials for concrete were brought in barges to a point opposite the block being cast, and these materials were transferred from the barge to the hopper of the concrete mixing plant by clamshell bucket operated by a link-belt locomotive crane moving on a track parallel to and behind the canal wall. The concrete mixing plant was movable, running on a track in the bottom of the pit and adjacent to the new wall. A Smith mixer, capacity 31 cubic feet, was used for mixing the concrete, which was then dumped into a bucket and lifted by means of a tower, 50 feet high, and thence was carried by flexible Wiley chutes to the top of the form, and into the form by short lengths of zigzag chutes. The power for mixing and hoisting the aggregate was supplied by 20 and 40 horsepower electric motors, connected to the local mains. The average power consumption per cubic yard of concrete placed by this plant was 0.4 K.W. hour. The cement was hauled by teams from the storehouse across the canal to the standard gauge track leading into the pit near 18th street, there loaded into cars provided with housing arrangment for weather protection and thence hauled by locomotives to the mixing plant. This plant has a maximum capacity of mixing and placing 50 cubic yards per hour with an average of 35 cubic yards per hour. This concrete plant and

form equipment has a record of thirty-five sections, of about 140 cubic yards each, in thirty-five consecutive working days.

All plain concrete is mixed in the proportion of 1 barrel of cement, as packed for shipment, 11 cubic feet of sand, 24 cubic feet of gravel and sufficient clean water to form a mixture requiring little tamping, the quantity of water being varied to suit the conditions. Before placing concrete, the rock bed and adjoining concrete surfaces were thoroughly cleaned, wetted, and covered with a layer of mortar ½ inch thick, composed of 1 part cement to 2 parts sand. The faces of all concrete surfaces were formed by working the gravel away from the form with spades, so as to leave only mortar next to the forms. Immediately after the removal of the forms, all surface defects were repaired. The top of the wall was finished with a floating tool and the joints between monoliths at the top of the wall were made with a jointing tool. Local brands of Portland cement, stored in weatherproof sheds, were used and tested in accordance with the United States Government specifications for Portland cement. A sufficient quantity of cement is kept on hand to allow for the twenty-eight day test before use. The sand and gravel used is excavated in the Ohio River and supplied by local dealers. The sand is required to pass through a screen having four meshes to the inch, be clean, free from foreign matter and show, when shaken in water and allowed to subside, a total clay constituent of not more than 5 per cent, by weight. The gravel is required to pass through a 2½-inch screen and be retained on a ¼-inch screen. As a rule, the sand furnished met all requirements, but the gravel was often too small and not well graded. The demand for gravel in the local markets is largely for reinforced concrete aggregate, and for this reason the screening plants on the gravel dredges have been arranged accordingly.

At the foot of the canal and adjacent to the three small locks, which were constructed in 1828-1830 and later abandoned, the Government maintains a dry dock for the construction and repairs of floating plant used on the Ohio River. For unwatering this dry dock, a drain at its lower end connected with the old lock chambers and thence with the river below the locks. Water from the canal was prevented from passing through the old locks by heavy wooden guard gates. These gates were very old and needed to be replaced by new ones, or by some other structure. Inasmuch as it was planned to fill the old lock chambers, it was decided to replace the

lock gates by a headwall of masonry to limit the fill on the canal side, and to prevent undue percolation through the newly made fill. As the lock chambers were to be filled, it was necessary to extend the dry dock drain from its entrance into the lock chambers along their length to the river below, so that the dry dock may be unwatered.

While the contractor was preparing for the main work of widening the canal, he built the head wall behind the lock guard gates, using two small Smith mixers, capacity ½-yard and ¾-yard, operated by steam. The construction of the extension of the dry dock culvert was begun early in the summer of 1913 and completed during the summer of the next year. This structure is rectangular, 4 by 6 feet inside dimensions, with floor 10 inches and roof and sides 12 inches thick, and of concrete reinforced with ⅜ and ¾ inch square twisted steel. The concrete for this culvert conformed to all the requirements for plain concrete, except that the gravel was required to pass through a 1-inch screen and the mixture was changed to 1 barrel of cement, 7 cubic feet of sand and 14 cubic feet of gravel per batch. This culvert is 670 feet long and about 470 feet of its length was carried directly on the rock ledge, but at the lower end there was a 10-foot drop of rock surface and piers were necessary. The only difficulty in constructing this culvert was due to a deposit in the lock chambers of about 20 feet of mud. An open trench through this mud was excavated within wooden sheeting by means of stiff-leg derricks with clamshell buckets. The river water was excluded from the work by the construction of an interlocking steel piling cofferdam below the outlet end of the culvert. While driving the trench sheeting, near the sill of the middle lock chamber, an obstruction of considerable interest was encountered. This was found to the north leaf and sill of the middle gate. Despite an age of fifty years or more, the timber of these structures was comparatively sound, only the exterior fibers being slightly decayed.

Pumping by means of Nye pumps was necessary throughout this work. Leakage occurred largely from the river, the subgrade of the trench at the discharge end being about 9 feet below low water. Prior to construction of this extension, the existing culvert had been discharging into the canal chambers at the mid-point of the lock. In order to prevent the flow of water from the canal through the existing culvert, the dry dock gates were closed, the dock drained and the inlet end of the culvert closed by bracing the

gate with heavy struts and placing a sack dam in the culvert. After excavation of the mud had been carried to rock and the foundation properly prepared, the forms for the floor and side-walls were placed and the concrete placed in sections from 20 to 30 feet in length. After this concrete had thoroughly set, the roof forms were placed and the culvert completed. This work was carried on simultaneously at several locations. At the end of two weeks, backfilling to the height of 10 feet was made. The inside forms were later removed. Owing to early high river

Fig. 8. Direct Lift Bridge, Louisville and Portland Canal, Lowered. July 16, 1915.

stages, it was not possible to complete this work as originally planned during the first season.

During 1914 only, the work was carried on in two 8-hour shifts per day. It was found that the increased output, by working two shifts, was not proportional to the increased cost. The overhead and pumping charges were the same whether one or two shifts were worked, but owing to poor lighting conditions during the latter part of the second shift the labor was inefficient and the added cost of labor more than counterbalanced the saving in over-head and pumping charges.

The work of removing the old canal wall and the underlying rock ledge is to be done as subaqueous work by dredge and derrick-boat. This work includes about 25,000 cubic yards of excavation. It was the opinion of the contractor that the small amount of work involved would not warrant the purchase or rental of the necessary floating plant, and for this reason the work was sublet to the Western Rivers Dredging Company. The removal of the two upper courses of a thousand feet of this wall has been accomplished to date.

On account of widening the canal, it was necessary to replace the old swing bridge over the canal at 18th street. This was done under separate contract and a lift bridge was installed, having a clear span between piers of 204 feet and a clear vertical lift of 40 feet. This bridge was designed by the Strauss Bascule Bridge Company and constructed by the Penn Bridge Company[1] (Fig. 8).

It is believed that the following cost data are valuable, as they are based upon the Government and the contractor's field office records, compared and adjusted with the main office records of the Henry Bickel Company by Mr. A. G. Butler, Superintendent, and Junior Engineer Robert A. Strecker, Government Inspector in Charge (Tables 2 and 3).

During the period included in this report, progress of the work has kept pace almost uniformly with the contract time allowed, in spite of the unfavorable weather conditions during four months of each year, difficult plant erection, and the failure of the old wall while being used as a cofferdam. The contract has been prosecuted with intelligence and energy. The methods employed have been excellent and the plant selected was suitable for the work to be done. The prosecution of this work has been as successful from the Governmental point of view as that of any other Government contract with which the writer has had experience.

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[1]For additional information relating to this bridge, reference is made to PROFESSIONAL MEMOIRS, Vol. 6, No. 29, "Works at the Falls of the Ohio River," and Vol. 7, No. 35, "Direct Lift Bridge Across Louisville and Portland Canal," by Maj. J. C. Oakes, Corps of Engineers.

	79.04	19.77	19.76
	$1,495.32	$373.37	$353.81

TABLE 2.—*Cost of Materials and Supplies.*

Quantity.	Unit.	Item, Designation, Etc.	Total cost.	Distribution of Costs. Common excavation	Rock excavation	Channeling.	Plain concrete.	Reinforced concrete.	Macadam roadway.	24-in. C.I. culverts.	Reinforcing rods.
13,016	Tons	Coal	$40,870.28	24,343.70	13,400.45	1,496.60	145.95	681.65	801.93		
17,768	Barrels	Cement	20,724.25		798.72		18,765.28	1,134.83		25.42	
104,000	Pounds	Dynamite	14,372.78		14,372.78						
1	Lot	Track Material ... Total, $17,606.06	12,606.06	5,798.79	6,807.27						
16,066	Cubic yards	Gravel	7,883.27		1,030.72		6,623.09	220.46		9.00	
7,926	Cubic yards	Sand	3,295.50	148.97	519.40		2,536.96	87.02		3.15	
300	Pieces	Lackawanna Steel Sheet Piling ... Total, $3,508.37	1,008.37	35.90	608.31		304.16	60.00			
1	Lot	Oil, Waste, and Grease	2,906.84	1,510.55	813.91	129.54	378.89	46.56	27.39		
1	Lot	Electrical Supplies ... Total, $4,762.39	4,262.39		2,983.67		1,278.72				
1	Lot	Miscellaneous Tools ... Total, 2,016.76	1,008.38	524.36	282.34	23.19	131.09	17.14	20.18	5.05	5.03
1	Lot	Water and Steam Pipe ... Total, 2,090.92	1,643.19	854.46	460.09	82.16	230.05	16.43			
1	Lot	Wire Cable Line	2,006.52	1,605.22			401.30				
		Lumber—									
275	M. B. M.	Trestles	7,920.06	3,643.23	4,276.83						
116	M. B. M.	Dry Dock Culvert	2,822.15	2,822.15							
16	M. B. M.	Temporary Approach	529.49	275.33	148.26	12.18	68.83	9.00	10.59	2.65	2.65
7	M. B. M.	Draglines	248.70	248.70							
7		Dump Cars	228.21	104.98	123.23						
11		18th Street Bridge Pier	272.93				272.93				
5		Locomotive Sheds	110.47	50.82	59.65						
4		Pump Houses	96.71		96.71						
3		Cement House	70.89				70.89				
3		Thew Shovels	62.40	62.40							
0.5		Locomotives	41.90	19.28	22.62						
2		Rock Crusher	28.01						28.01		
1		Air Compressor House	17.25		17.25						
0.5		Marion Shovel	11.50	2.90	8.60						
		Drill Steel ... Total, $1,179.17	707.51		707.51						
		Channeling Steel ... Total, 1,204.13	722.58		240.89	481.69					
1	Lot	Detonators	2,659.19		2,659.19						
1	Lot	Steam Hose	790.61		790.61						
1	Lot	Manilla Rope	580.40	193.47	193.47		193.46				
140,904	Pounds	Culvert Pipe	1,600.08							1,600.08	
64,524	Pounds	Reinforcing Rods	1,032.38								1,032.38
45,614	Pounds	Anchor Rods	821.05				821.05				
213	Tons	Screenings	150.00						150.00		
		Weep Hole Forms	135.30				135.30				
		Form Tie Rods and Sleeves	696.80				696.80				
		Calking Material for Old Wall	826.23		826.23						
		Rubber Boots	234.57	234.57							
		Iron Check Posts	35.00				35.00				
		"I" Beams ... Total, $443.34	177.34	88.67	53.20	5.32	17.73		12.42		
		Vitrified Pipe	269.30		269.30						
		Miscellaneous Fittings, Paint, Packing, Etc.	2,471.15	1,235.58	741.35	123.56	296.54	49.42	24.70		
		Totals	$138,957.99	43,804.03	53,312.56	2,354.24	33,404.02	2,322.51	1,075.22	1,645.35	1,040.06

Labor Costs: Skilled and Unskilled Labor, and Teams.

Common excavation	$144,259.98
Rock excavation	113,451.50
Channeling	13,280.58
Plain concrete	28,788.05
Reinforced concrete	2,375.97
Macadam roadway	5,752.28
24-inch C. I. culverts	791.38
Reinforcing rods	867.17
Total	$309,566.91

Recapitulation of Costs.

Item.	Total cost.	Distribution of Costs. Common excavation.	Rock excavation.	Channeling.	Plain Concrete.	Reinforced Concrete.	Macadam Roadway.	24-in. C. I. culverts.	Reinforcing rods.
Labor	$309,566.91	144,259.98	113,451.50	13,280.58	28,788.05	2,375.97	5,752.28	791.38	867.17
Material and supplies	138,957.99	43,804.03	53,312.56	2,354.24	33,404.02	2,322.51	1,075.22	1,645.35	1,040.06
Equipment	62,946.96	29,111.86	21,247.46	3,070.74	8,381.03	472.67	663.20		
Overhead expenses	86,015.59	39,360.48	31,575.25	1,742.73	9,822.55	1,292.08	1,495.32	373.37	353.81
Total cost to January 1, 1916	$597,487.45	256,536.35	219,586.77	$20,448.29	$80,395.65	$6,463.23	$8,986.02	$2,810.10	$2,261.04
Total paid to January 1, 1916	* 608,121.20	340,162.65	156,067.20	15,292.20	75,795.00	11,312.00	1,800.00	3,696.00	3,226.20
		Cubic yards.	*Cubic yards.*	*Sq. ft.*		*Cubic yards*	*Sq. yds.*	*Lin. ft.*	*Lbs.*
Total quantities to January 1, 1916		755,917	173,408	50,974	15,159	565.6	2,400	462	64,524
Total approximate contract quantities		762,000	215,000	52,000	17,000	565.6	17,000	186	64,524
Unit prices		0.45	0.90	0.30	5.00	20.00	0.75	8.00	0.05
Unit cost		0.339	1.266	0.401	5.303	11.429	3.744	6.083	0.035

*Includes $769.95 for extra work and Check Posts and $40,000 retained percentage.

Note: Overhead expenses were distributed by the straight-line method based on the total money value of the contract and the item values.
Field Superintendent and Main Office items include salaries paid members of the firm.
The equipment charge=depreciation of Plant+cost of repair parts (no labor).
First cost of Plant includes erection and assembling.
The Western Rivers Dredging Co.'s plant charge, materials, labor, etc., have not been included. The quantity of work (about 1,500 cubic yards) accomplished prior to January 1, 1916, is small, and has been ignored.

TABLE 3.—*Equipment Costs.**

No.	Item and Designation.	First cost.	Repairs.	Present value.	Net plant cost.	Distribution of Plant Costs. Common excavation.	Rock excavation.	Channeling.	Plain concrete.	Reinforced concrete.	Macadam roadway.
5	Porter Locomotives	$27,500.00	$953.85	$20,000.00	$8,453.85	$3,888.77	$4,565.08				
24	12-Cu. Yd. Western Air Dump Cars	25,440.00	942.04	17,808.00	8,574.04	3,944.06	4,629.98				
2	Dragline Excavators (Lidgerwood-Crawford)	23,000.00	2,547.77	12,000.00	13,547.77	13,547.77					
1	Marion Steam Shovel, Model 61	10,000.00	2,134.16	7,500.00	4,634.16	1,158.54	3,475.62				
1	Link Belt Crane	6,700.00	286.06	5,000.00	1,986.06	100.00	100.00		1,786.06		
1	Thew Steam Shovel, 1-yd. Dipper (Orig. Cost, $5,500.00)	4,100.00	196.87	3,300.00	996.87	805.12	191.75				
1	Thew Steam Shovel, ⅞-yd. Dipper (Orig. Cost, $5,000.00)	3,800.00	619.91	3,000.00	141.91	141.91					
1	Sullivan Duplex Channeler	4,300.00	1,370.37	2,580.00	3,090.37		1,545.18	1,545.19			
1	Ingersoll-Rand Channeler	3,200.00	743.40	1,920.00	2,023.40		505.85	1,517.55			
1	Ingersoll-Rand Wagon Drill	2,900.00	402.50	1,940.00	1,362.50		1,362.50				
5	Sullivan Tripod Drills	1,850.00	462.15	1,446.00	866.15		866.15				
2	Smith Concrete Mixers	1,488.00	278.43	1,190.00	576.43				103.76	472.67	
3	2 Cu. Yd. Page Buckets	2,322.00	83.55	1,395.00	1,010.55	1,010.55					
1	31 Cu. Ft. Smith Concrete Mixer	1,900.00		1,425.00	475.00				475.00		
3	12-in. Morris Centrifugal Pumps	2,400.00	163.39	1,800.00	763.39		763.39				
1	Spreader Car (Oliver)	1,500.00		900.00	600.00	600.00					
3	Sets Blaw Steel Forms ... Rental	5,600.00			5,600.00				5,600.00		
1	Lidgerwood 3-Drum Engine	846.00	13.60	846.00	13.60	13.60					
1	Lambert Engine	720.00	80.59	720.00	80.59		54.80		25.79		
1	Mundy Double Drum Engine	950.00	100.64	570.00	480.64	480.64					
1	Mundy Single Drum Engine	650.00		390.00	260.00		260.00				
1	Beyers Double Drum Engine	600.00		480.00	120.00	78.00	42.00				
5	3-inch Nye Pumps	1,250.00		936.00	314.00	314.00					
1	Road Roller	960.00		800.00	160.00						160.00
1	Jaw Rock Crusher	750.00		400.00	350.00						350.00
1	Portable Air Compressor	1,200.00	30.00	720.00	510.00		510.00				
1	Motor-Driven Air Compressor	900.00	186.30	540.00	546.30		546.30				
1	Horizontal Boiler	800.00		480.00	320.00		320.00				
1	Vertical Boiler	350.00		210.00	140.00		140.00				
1	1 Cu. Yd. Clam Shell Bucket	500.00	11.73	300.00	211.73	211.73					
1	¾ Cu. Yd. Clam Shell Bucket	450.00	11.72	270.00	191.72	191.72					
1	1½ Cu. Yd. Page Bucket	673.00	27.85	605.00	95.85	95.85					
4	Cableway Buckets	200.00		120.00	80.00		80.00				
5	Ingersoll-Rand Jackhammer Drills	500.00	182.93	375.00	307.93		307.93				
2	B. A. No. 23 Ingersoll-Rand Drills	200.00		50.00	150.00		150.00				
1	Hoisting Engine	1,100.00		831.00	269.00				269.00		
1	Portable Engine	750.00		600.00	150.00						150.00
1	Monarch Pile Hammer	600.00		480.00	120.00	120.00					
1	6-inch Buffalo Centrifugal Pump	500.00	32.23	375.00	157.23		106.92		50.31		
1	6-inch Nye Pump	500.00	32.23	375.00	157.23		106.92		50.31		
1	4-inch Nye Pump	300.00	19.84	225.00	94.84		94.84				
1	Sheeting Hammer	150.00		100.00	50.00	50.00					
2	Gondola R. R. Cars	250.00		250.00							
2	Lidgerwood Engines	720.00	9.27	432.00	297.27	297.27					
2	Hold Drum Engines	220.00		165.00	55.00		55.00				
1	Swinging Engine	225.00		135.00	90.00	90.00					
1	15 H. P. Motor	200.00		150.00	50.00	26.00	14.00	2.50	6.50		1.00
1	Drill Press	100.00		25.00	75.00	39.00	21.00	3.75	9.75		1.50
1	Stiff-Leg Derrick	75.00		60.00	15.00	15.00					
1	Wagon Scales	85.00		75.00	10.00	5.20	2.80	.50	1.30		.20
2	Diaphragm Pumps	60.00	2.45	40.00	22.45		22.45				
1	Rivet Gun	40.00		25.00	15.00	7.80	4.20	.75	1.95		.30
1	Machine Grinder	25.00		15.00	10.00	5.20	2.80	.50	1.30		.20
	Plant Rental	996.13			996.13	596.13	400.00				
	Totals	$147,395.13	$11,925.83	$96,374.00	$62,946.96	$29,111.86	$21,247.46	$3,070.74	$8,381.03	$472.67	$663.20

*No entries having been made in the columns under the headings "24-inch C. I. Culvert" and "Reinforcing Rods," they were omitted in print.

Overhead Costs.

Item, Designation, Etc.	Total cost.	Distribution of Cost. Common excavation.	Rock excavation.	Channeling.	Plain concrete.	Reinforced concrete.	Macadam roadway.	24-in. C. I. culvert.	Reinforcing rods.
Main Office	$9,600.00	$4,992.00	$2,688.00	$220.80	$1,248.00	$163.20	$192.00	$48.00	$48.00
Surety Bond	9,841.00	5,117.32	2,745.48	226.30	1,279.33	167.34	196.82	49.20	49.21
Liability Insurance	14,675.44	7,631.32	4,109.12	337.44	1,907.84	249.48	293.51	73.38	73.38
Taxes	1,755.00	912.60	491.40	40.15	228.15	29.84	35.10	8.88	8.88
Interest on Borrowed Capital	12,812.64	6,662.59	3,587.54	294.69	1,665.64	217.81	256.25	64.06	64.06
Field Superintendence	11,985.00	6,232.20	3,355.81	275.65	1,558.05	203.75	239.70	59.92	59.92
Clerical and Timekeeping	6,120.00	3,182.40	1,713.60	140.76	795.60	104.04	122.40	30.60	30.60
Lighting	756.19	483.96	249.54	22.69					
Power	10,492.87		10,388.87		104.00				
Water	3,915.00	2,035.82	1,096.20	90.04	508.95	86.13	78.30	19.56	
Property Tax	110.30	55.15	33.09	3.31	13.24	3.31	2.20		
Freight, Express and Drayage	3,952.15	2,055.12	1,106.60	90.90	513.78	67.18	79.04	19.77	19.76
Total	$86,015.59	$39,360.48	$31,575.25	$1,742.73	$9,822.55	$1,292.08	$1,495.32	$373.37	$353.81

Cofferdam for New Locks at St. Marys Falls Canal, Sault Ste. Marie, Mich.

ITS DESIGN, CONSTRUCTION AND COST.

BY

Mr. W. J. Graves,
Assistant Engineer.

The new 1,350 by 80 foot ship locks at Sault Ste. Marie, Mich., required the construction of a cofferdam around the site of the locks as a preliminary step. The project for "New Lock and Canal," as set forth in House Document No. 333, 59th Congress, 2d session, was inaugurated in December, 1907, when work on this cofferdam commenced. Its construction covered a period of two and a half years, to May, 1910, although practically completed during the summer of 1909, in time for the letting of the final contract for lock pit excavation. The area was first unwatered on September 27, 1909.

The work was begun under the direction of Col. Chas. E. L. B. Davis, Corps of Engineers, and continued under the direction of Col. C. McD. Townsend. Mr. L. C. Sabin, Assistant Engineer, resident engineer in charge of construction, was directly responsible for the design and construction of the dam.

General Description. The total length of new cofferdam constructed was 3,153 feet, while 1,074 feet of existing masonry and 671 feet of old dam, built in connection with the work on the Poe lock in 1894, brought the total length of water, excluding wall, to 5,281 feet. The area inclosed by this mile of structure was 980,500 square feet, or 22.51 acres, and the work built or to be built within its confines will cost about $6,000,000.

The original preliminary estimate of cost of project for new lock and canal (House Document No. 333) provided for the construction of a cofferdam 6,000 feet in length, inclosing the site of a portion of the new canal as well as the lock proper, at an estimated cost of $270,000. The 3,153 feet of new dam finally built around the site of the new lock cost $86,290, and the remaining

canal cofferdam of simpler type was included in the subsequent contract for canal construction, without special payment therefor.

Location. The axis of the new lock was made parallel with the existing locks in a general east and west direction. The site was bounded on the south by the masonry of the Poe lock and its timber pier approaches, on the west by the water of a power plant headrace, on the north by a tailrace and the St. Marys River, and on the east by the river, as shown on the accompanying map, Plate I, which also shows the final outline after completion of the dam.

Within the area stood the remains of an abandoned power plant with its headrace and tailrace, also a large frame building, surrounded by small ponds, used as a fish hatchery. The original shore line is shown on Plate I by broken line.

Design in General. A considerable part of the immediate boundary was land, rather than water, but of such character that it could not be depended upon to exclude water from the pit.

A survey of conditions preceded the design and construction of the various sections. When the overburden did not exceed 10 feet in depth the test driving to rock was done by hand, using a blunt pointed steel rod, 1 inch in diameter. In other places a 3-inch steel shaft, provided with a detachable blunt point, was driven with a pile-driver. A special rigging was devised for pulling the rod up after rock had been reached. Test holes were spaced from 10 feet to 20 feet apart along the line of the proposed dam. While these tests gave a good general indication of the rock elevation, it was found that in some cases the hand driving did not pierce the overlying hardpan, and that the heavy machine work sometimes penetrated the soft upper strata of rock. The cost of this survey, not included in the cost of cofferdam, amounted to $1,700, or about 45 cents per foot of hole. Average depth of hole, 14.5 feet.

Character of Material. In some places the embankment was a porous, loose rock dump; at other localities, principally along the north side, the overburden consisted of a layer of boulders, then gravel, underneath which was a layer of treacherous silt. This latter material is a very fine grained and densely compacted material that resists, like rock, the penetration of a test drive rod, but when exposed to the action of running water, immediately washes away. When agitated in still water it turns to mud and remains in suspension for a time, then settles back as firmly as ever. This

PLATE 1.

AN.

OCKS

L

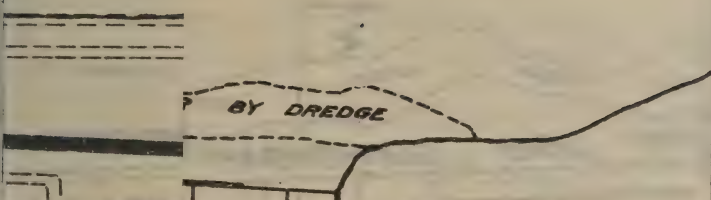
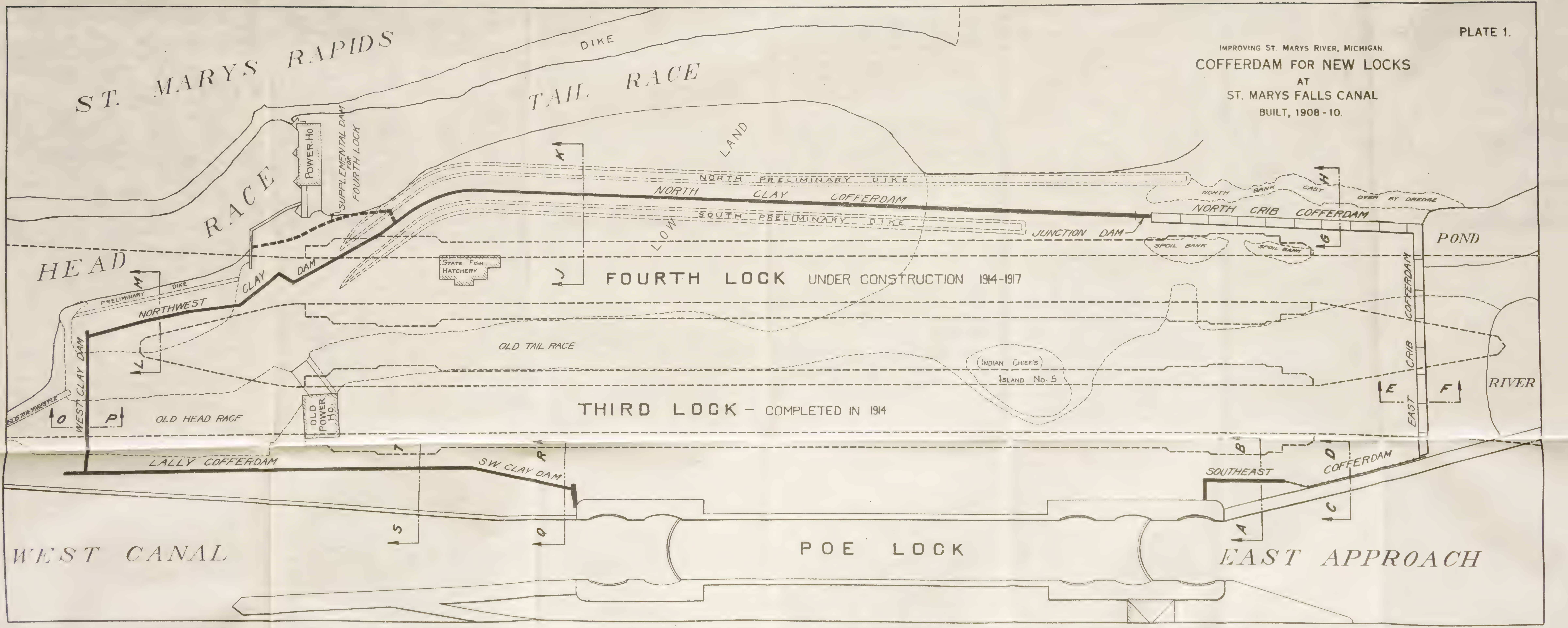


PLATE 1.

IMPROVING ST. MARYS RIVER, MICHIGAN.

COFFERDAM FOR NEW LOCKS AT ST. MARYS FALLS CANAL

BUILT, 1908-10.



feature caused some trouble in placing of timber cribs on rock, as mentioned later.

The failure of the Poe lock cofferdam and consequent flooding of the pit, by the washing away of the underlying silt, served as a warning that all new lock cofferdams must be founded on bed-rock. Some excavation was required for every foot of dam, as bare areas of bed-rock did not exist.

Fundamental Principle. The entire structure of any cofferdam it as tight as the weakest place; therefore care must be taken with the design and construction as regards tightness, especially when fitting to the bottom or where one section or type of construction connects with another.

Division of the Structure into Sections. The dam was designed and built in nine different sections, designated by names. These sections were of different types of construction, built by different methods, and at various seasons of the year, as seemed most expedient. Some sections were built by hired labor, some under small contracts and others by a combination of the two methods. One feature common to all sections was the placing of backfilling and crib-filling under minor contracts for "lock pit excavation," let from time to time as the material was needed. Considerable saving in cost was thereby effected, as the material was dumped without cost other than for excavation.

Plate I shows the alignment and division points between the various sections.

The location of the west end dam was determined partly by existing local conditions and partly to bring the new center pier masonry construction in the dry.

The location of the north dam was such as to provide for the construction of a possible fourth lock (now a reality), as well as the third lock. The wisdom of this plan was proved by the ease and dispatch with which the contract work on fourth lock excavation was inaugurated in 1913.

The east dam was placed as far east as possible and still be sure of a rock foundation above established grade of the canal (elevation 70). About 150 feet of east approach walls were thereby brought within the dam.

Types of Construction. The types of construction varied from a timber crib, rock-filled structure, subject to a direct pressure of 23-foot head, to land portions of clay puddle wall, only a few feet

high, to prevent possible seepage through existing embankment 60 feet or more in width.

DESIGN, METHODS, AND COST OF CONSTRUCTION OF THE VARIOUS SECTIONS.

Southeast Dam. The *westerly portion* of this section (Fig. 1) is a clay puddle wall 4 feet thick, built within a sheathed trench excavated by hand to such depth as to uncover the clay of the old Poe lock cofferdam at about elevation 94. As there was some uncertainty as to the quality of the clay in this old dam, as well as its contact with the underlying rock strata, triple-lap oak sheet-piling was driven along both sides of the superimposed puddle wall, down through the clay of the old dam to rock. As the top of slope into the pit came close to this wall, insufficient banking was left and the top of the sheet piling was therefore tied back to the timber canal wall with 1½-inch rods, spaced about 16 feet apart. This section is 144 feet long and averaged 20.9 feet in depth. The work was performed by hired labor at the following cost:

Labor and supplies	$2,676
Material: Oak plank, clay and iron rods	2,224
Total cost	$4,900

or $34.02 per linear foot, or $1.62 per square foot of wall.

The *easterly portion* of this section (Fig. 2) is 265 feet long and consists of 25-foot lengths of 40-pound Lackawanna steel piling, driven through a loose rock fill to bed rock. The steel piling extended 4 feet into the clay puddle wall at either end, thereby making a good tight connection between the two types of dam. For the reason that the slope into the pit came within 10 feet of the top, this sheathing was also tied back with rods spaced about 20 feet apart. The work was all performed by hired labor at the following cost:

Labor, supplies, etc.	$1,007
Steel piles and rods	5,358
Total cost	$6,365

or $24.02 per linear foot, or 96 cents per square foot of wall (salvage not considered).

It was known that this piling must be driven through loose rock and boulders. To make sure that its use would be practicable,

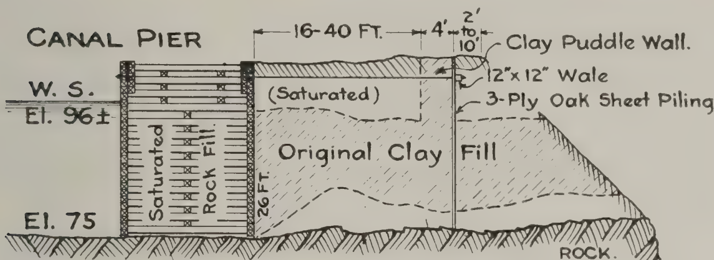


FIG. 1 SEC. A-B

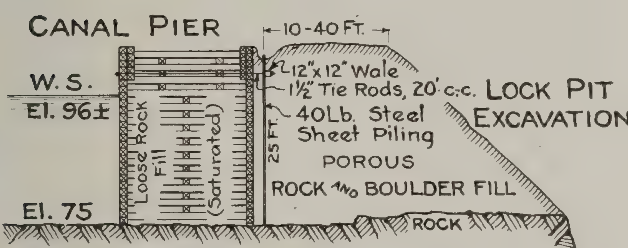


FIG. 2 SEC. C-D

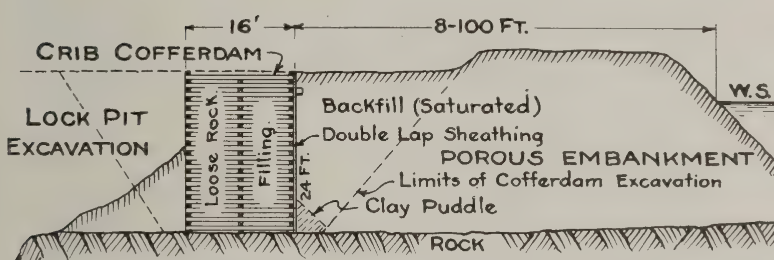


FIG. 3 SEC. E-F

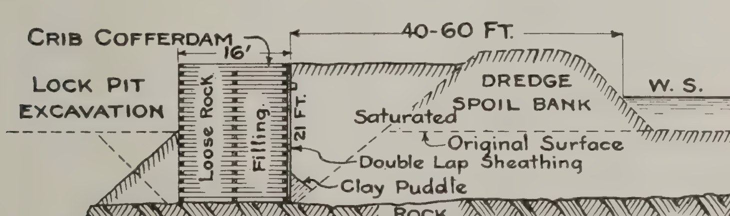


FIG. 4 SEC. G-H

ten pieces were purchased first for experimental driving. It is quite possible that its close proximity to the back of a timber crib may have had something to do with the ease of driving. Boulders were frequently struck, but were pushed aside or else the pile twisted slightly, resulting in a curved line around the boulder. Extraction and redriving at a litle different angle was necessary in some cases.

In view of the low cost per square foot, practically the same as for clay puddle wall, the steel piling might have been used advantageously on some of the other sections of dam. It would certainly have saved time, but as practically every other section went through a mass of boulders, large and small, the possibility of driving was problematical.

Salvage. No credit is given in cost summary for salvage on steel piling, for the reason that it was cut off to top grade and left in place.

Cutting Steel Piling. A local firm contracted to furnish an oxy-acetylene torch outfit and operator at $5.00 per hour. About 50 feet of heaviest section was cut at a cost of $1.20 per foot.

North Crib Dam. (Fig. 4.) Excavation: This section was the first to be built in the wet. But little dredging was necessary to complete a trench 27 feet wide at the bottom, in which the timber cribs 16 feet wide were founded. This dredging started at the east end and was carried inland, toward the west, as far as the elevation of bed rock would permit of floating a dipper dredge drawing 9½ feet of water.

Removal of Large Boulders. The dredge encountered a boulder $9' \times 10' \times 12'$ in size, which it was necessary to drill and blast, at a cost of $97.00. The pieces were then removed by chaining to the dipper teeth.

Crib Construction. The cribs were 16 feet wide, 40 feet long and 21 feet high. They were built of 8 by 8 inch hemlock timber. To lessen the cost of construction, on work of such temporary nature, as well as to facilitate their removal later by dredging, they were built corn-cob style, the intersecting timbers being drift-bolted with ½-inch bolts. The ends of the face and back wall timbers projected 6 inches beyond the outside of the end tie walls, thereby leaving a 12-inch space between the end walls of abutting cribs. Into this space were driven framed locking bents of 12 by 12 inch timber. This novel scheme worked well, as the cribs were forced into good alignment and held there as firmly as though

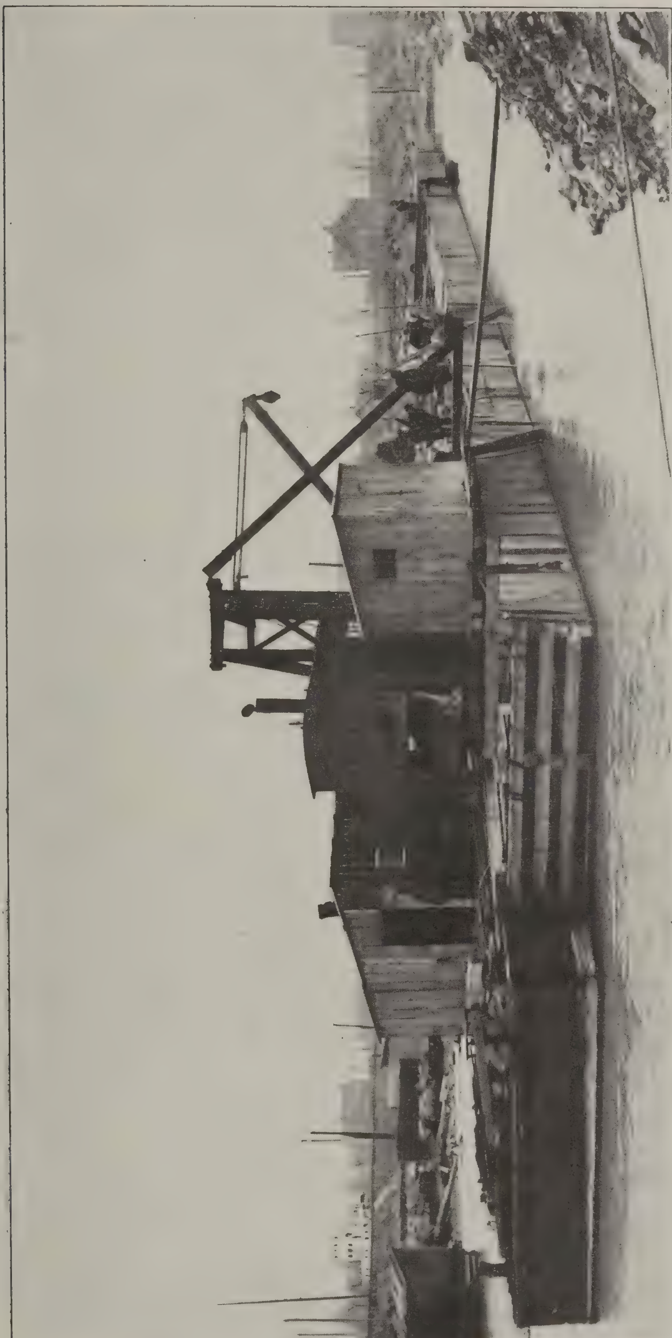
North Crib Dam. Lower portion of one 43-foot section of "corn-cob" crib ready for launching. Note sheathing on the face.

the cribwork had been built as a continuous structure. The cribs were started on shore, and when about 6 feet high the 1 inch vertical matched sheathing was nailed onto the side walls and the crib launched, the remaining 15 feet being added after flotation. Oil barrels were employed as buoyancy pontons during the latter stages of construction and placing. The bottoms of the cribs were built to conform to the uneven rock bottom, as determined by soundings taken 3 feet apart along the line of the crib walls.

Placing Cribs. Considerable difficulty was experienced founding cribs on the rock. During the interval of several months which elapsed after dredging, considerable material settled over the bottom in a hard compact layer and, furthermore, the dipper dredge failed to clean the bottom in a satisfactory manner. A derrick boat and diver were employed to pick up the coarser material. The cribs were then floated to place and sunk. A small drag-line scraper, guided by a diver, was first employed in an unsuccessful attempt to seat the cribs. A water jet, with 3/8-inch nozzle, under pressure varying from 60 to 120 pounds, was then employed successfully, although the amount of material to be cleared away was so great that an 8-inch centrifugal sand pump, running at 450 r. p. m., was operated to remove the material as fast as loosened by the jet. The 8-inch suction pipe was pivoted to permit of dragging along the bottom. The divers, working four-hour shifts, so manipulated the jet that the material was driven toward the suction, which removed it instantly, allowing the weighted crib to settle into place. Part of this clean-up work was performed during winter months, and the diver's air pump was housed in a heated shed on the crib to permit him to work without discomfort. The removal of ice around the cribs proved an added disadvantage and expense.

After the cribs were placed, clay was deposited along the outer toe, about 1 cubic yard to the linear foot of crib. Two-inch hemlock sheathing was then driven into this clay and secured by a wale near the top. Care was taken to have this driven sheathing break joints vertically with the 1-inch sheathing, previously nailed to the outside of the crib, thus forming double-lap sheathing practically watertight.

The cribs were filled and backfilled with a mixture of earth and loose rock of smaller size.



North Crib Dam. Placing cribs. Diver engaged in clearing the way for settlement and fitting to bed-rock.

The cost of the north crib dam, 432 feet long, was as follows:

Contract dredging, 10,538 cubic yards	$5,286
Materials—timber, iron and clay	5,198
Labor and supplies	6,213
Total cost	$16,697

or $38.65 per linear foot, or $1.85 per square foot of wall.

East Crib Dam. (Fig. 3.) The embankment originally covering the site of this section was known to be a porous loose rock fill, through which a dry trench could never be excavated. The section was easily accessible for a dipper dredge, and the crib type of dam was therefore adopted. The crib work of the north dam continued around the northeast corner and extended to within 4 feet of the back of the canal pier forming the approach to the Poe lock. This 4 by 16 foot space was sheathed and puddled full of clay. The line of steel sheet piling of the "southeast dam" extended 8 feet into this clay, or to the center line of the cribs, thereby making a good watertight junction of the two types, at the southeast corner.

The east dam was 402 feet long and, except for the dredging, was built by hired labor at the following cost:

Excavation—contract dredging, 15,597 cubic yards	$10,154
Materials—lumber, iron and clay	4,311
Labor, supplies, etc.	6,200
Total cost	$20,665

or $51.40 per linear foot, or $2.39 per square foot of wall.

North Clay Dam. (Fig. 5.) This land portion, 1,300 feet long, consists of a clay puddle wall, 4 feet or more thick, built within a narrow trench excavated to rock; except for the uppermost 3 or 4 feet of wall, it was built without sheathing. The trench, excavated in winter, usually remained dry and stood with nearly vertical sides, the clay being puddled directly into it.

Winter Work Cheaper than Summer Work. The construction of this north dam demonstrated that certain kinds of work could, under existing conditions, be carried out cheaper in winter. For example: The amount saved in pumping was greater than the added expense of drilling and blasting frozen material. And again, the winter cost of clay delivery, when 5 yards could be hauled at each load across the ice without rehandling and dumped directly into the trench, was but 40 per cent of the cost for summer de-

livery. The saving thus effected more than made up for the added winter cost of thawing the clay. (Fig. 5.)

Preliminary Dikes. The site of the north dam lay in what was once the bed of the rapids, and at times of high water was partially inundated. To exclude this surface water from the trench, two low embankments, 50 to 60 feet apart, one down each side of the dam, as shown on Plate I, were constructed of material excavated from the lock pit under a minor contract. As the material was dumped on frozen ground or ice, the embankments proved ineffectual in excluding surface water when most needed, at the time of the thaw-out in the spring. The effect was not serious, as the embankments, built without cost other than for excavation, eventually served as backing for the clay wall.

Stripping Boulders in Winter. The site was covered with a layer of boulders large and small, which were removed from an

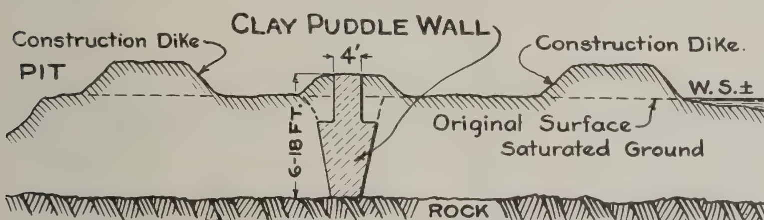


FIG. 5 SEC. J-K

area 40 feet wide along the line of the proposed dam before starting the trench excavation. Nine men working one month removed 721 cubic yards of boulders from 1.15 acres of ground, at a cost of 76 cents per yard, or $475 per acre. Many of the boulders were firmly embedded in gravel and frozen and could have been removed at less cost in summer. The stones were moved an average distance of but 20 feet, and piled along one side of the area. The stones were pried or blasted loose, the smaller ones carried by hand and the larger ones raised with chain falls suspended from a light tripod derrick and lowered onto a hand truck and hauled over improvised plank runways to the dump. Fifty-four of the largest boulders, averaging 2¾ yards each, were drilled by hand and cracked with dynamite.

Trench Excavation, Clay, Etc. A force of fifty hired laborers, many of whom were from the regular lock force, dug the trench through frozen gravel and placed the clay in about four months time. The trench was from 3 to 15 feet deep. When a section of trench three to four hundred feet long was completed, it was

partitioned off with plank bulkheads and filled with clay dumped from sleighs driven alongside. The clay was deposited in layers from 6 to 24 inches thick, depending upon how badly the lumps were frozen, then puddled with hot water. When necessary, the layer of frozen clay was covered with tarpaulins under which steam was allowed to exhaust over night. The puddlers wore rubber boots and used wooden rammers. A 10-horsepower portable boiler was used for thawing purposes. Clay for puddling must be a heavy, sticky clay, free from loam. For this work an exceptionally good quality of red clay was available in a bank located 1½ miles from the dam. It was loaded and team-hauled under contract. Clay shrinks 33 1-3 per cent from box measure when puddled in place. When the wall projected above the original ground surface it was confined by sheathing of second-hand 1 inch lumber, placed horizontally like a fence, the upright posts being braced with short braces.

Cost Summary.		Unit.	Cost.
Stripping boulders		$0.76	$545
Excavating trench, 2,845 cubic yards		2.96	
Labor	$7,677		
Supplies	756		
			8,433
Clay wall, 3,000 cubic yards—			
Labor	$2,040		
Supplies	187		
			2,227
Clay, 4,790 cubic yards box measure		0.438	2,099
Backfilling, 550 cubic yards—labor		--------	1,092
Total cost		--------	$14,396

or $10.96 per linear foot, or $0.934 per square foot of wall.

Junction Dam. A clay puddle wall between 2-inch vertical sheathing, then backfilled. This section, but 30 feet long, is a continuation of the North Clay Dam, connecting it with the crib, or water, portion. It was built in the summer time at high cost for excavation and for clay. The work performed by hired labor and in the dry, necessitated heavy expense for temporary sand-bag dams around the excavation and for pumping.

West and Northwest Cofferdams. Preliminary Dike. Means were at hand for building a rock-fill dike across the corner of the headrace, behind which, owing to natural drainage into the tailrace,

the cofferdam could be built in the dry. For this reason the type of dam selected was a clay wall rather than the crib type, built in the wet. Considerable saving in cost of cofferdam was thereby effected, especially as the preliminary dike was built by dumping material, then being excavated under contract, without any cost to the United States other than for excavation.

North Cofferdam. Dredge excavating trench for crib dam. Completed clay puddle wall in foreground.

The water was about 16 feet deep and the dike was from 20 to 30 feet wide at the water surface.

Unfortunately, an overturned Indian canoe was buried at the base of the dike and considerable leakage resulted. Another bad leak occurred at a point where dumping ceased for a couple of weeks. The finer material was washed from the end of the finished portion, leaving a well-defined plane of leakage. The

volume of water coming through became so great that its diversion could not be successfully accomplished, and it became necessary to stockram these leaks with clay before construction on the northwest dam could proceed.

Northwest Dam. (Fig. 6.) This section is a continuation of the north dam, about 190 linear feet being a low level clay puddle wall, 4 feet thick, built within a shallow trench, and about 350 feet, or the high level portion, is a clay puddle wall confined by elaborate timber sheathing set up within an open trench. The wall was afterward backfilled on both sides with loose rock. The work was per-

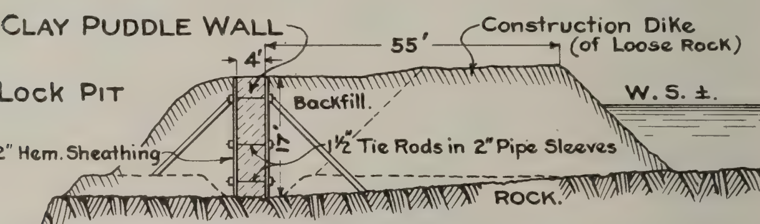


FIG. 6 SEC. L-M

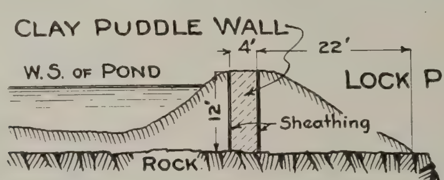


FIG. 7 SEC. O-P

formed in the summer. The cost of this section was as follows:

Development and incidental labor	$605
Excavation	3,744
Sheathing—labor and lumber	919
Clay wall—labor and clay	2,552
Backfilling—labor	1,149
Supplementary work—ramming leaks	1,711
Total	$10,680

Arresting a leak through a rock seam underneath the cofferdam was accomplished by capping the seam with a heavy concrete box from which a 4-inch iron pipe was led upward to such height that overflow into the tailrace was possible. The concrete was anchored firmly enough to resist the pressure due to the head of water—in this instance about 8 feet. This method was preferable to stopping

the leak by calking the rock seam, as past experience proved that a leak so stopped would later break out in another place. The box was about 4 feet square, and the outcropping seam was calked for several feet both sides of the box.

West Clay Dam. (Fig. 7.) A clay wall built in the summer. A portion lay in cut where no excavation was necessary, while another part passed through an embankment. The former wall was built

Northwest Cofferdam. Clay puddle wall and sheathing. Pile driver engaged in ramming clay cylinders down a 3-inch pipe to tighten leaks. Backfilling partially completed.

within sheathing held in place by backfilling. The backfill was carried up with the clay, the material being excavated simultaneously from the trench for the adjoining embankment section. The clay, delivered the previous winter to nearby stockpiles, was wheeled to place. A drain pipe for unwatering a nearby pit passed through this dam. The 10-inch pipe was provided with a collar 4 feet

square, made of plank. This collar was so placed as to fall within the limits of the puddle wall. When ready to pump out the lock pit, this pipe was closed by a wooden shutter, and never caused any trouble.

The cost for 258 linear feet of dam was as follows:

Excavation	$711
Sheathing—labor and lumber	292
Clay wall—labor and clay	1,632
Backfill—labor	572
Total	$3,207

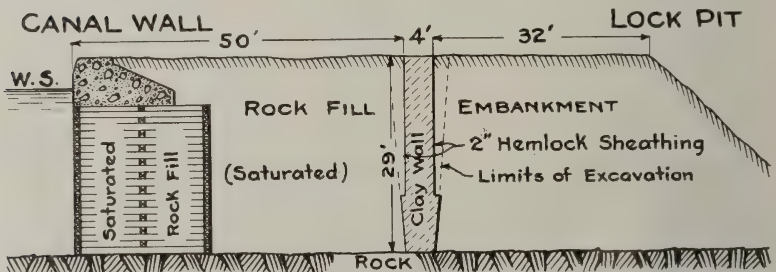


FIG. 8 SEC. Q-R

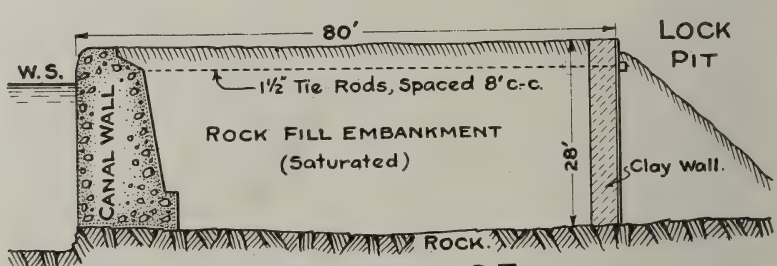


FIG. 9 SEC. S-T

or $12.43 per linear foot, or 97 cents per square foot of wall.

Southwest Clay Dam. (Fig. 8.) This short, but high, section of new cofferdam connected a long stretch of existing clay dam with the northwest corner of the Poe lock masonry, thereby completing about 1,766 linear feet of cut-off wall along the south side of the new pit. It was the only section let as a contract. The contractor failed and the work was completed by hired labor. A trench was excavated through frozen embankment to rock, the sides sheathed with 2-inch hemlock plank, placed vertically, then filled with puddled clay, giving a wall 5 feet thick. The maximum depth of trench

was 35 feet, and the length 179 feet. The cost of this section was as follows:

603 cubic yards excavation	$1,934
Sheathing—labor and lumber	420
Clay wall—labor and clay	1,102
Total	$3,456

or $19.31 per linear foot, or $0.64[1] per square foot of wall.

Supplemental Work on Southwest Dam. (Fig. 9.) An existing stretch of clay puddle wall, known as the "Lally" dam, and which was built in 1895 in connection with the construction of the Poe lock, formed a portion, 548 feet in length, of the new lock cofferdam. Owing to its close proximity to the top of slope into the Third lock pit, it was necessary to do some supplemental work along 240 feet of its length to make it secure against sliding. This work consisted in driving 6 by 12 inch hemlock sheathing a depth of 22 to 28 feet to rock along the north, or pit, side of the existing clay puddle wall, and anchoring it back to a concrete canal wall with 1½-inch tie-rods, spaced about 8 feet center to center. This protection was also extended to cover a portion of the southwest cofferdam before described. The work was performed by day labor, and cost as follows:

Materials—timber and iron	$2,550
Labor, placing	1,747
Stockramming leak with clay—labor and clay	375
Total	$4,672

or $12.24 per linear foot of wall sheathed.

REMARKS ON COST.

Clay Puddle Wall Costs. The last column of Table I gives the cost per square foot of vertical face area of completed wall. This unit cost seems the best basis of comparing the relative cost of the different types. It will be seen that simple clay puddle walls, without sheathing, cost 93 to 97 cents.

The southwest dam cost only 66 cents, because considerable work was done by bankrupt contractors without cost to the United States. If the United States could have been held liable, the cost would have been 96 cents per square foot, the same as for other clay walls.

[1]See note under "Remarks on Cost."

TABLE I.—*Cofferdam inclosing Lock Pit at Sault Ste. Marie, Mich.*

SUMMARY OF GENERAL DATA AND COSTS

Date of construction.	Name of section and kind of construction	Actual length constructed.	Average depth of excavation.	Normal head of water pressure on deepest part.	Average height of completed wall.	Actual face area of completed wall.	Costs (from Engineer's data). Total actual cost	Unit cost. Per lin. ft. of wall.	Unit cost. Per sq. ft. of wall.
November, 1908, to May, 1910	S. E. Cofferdam—two sections:	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. Ft.*			
	Clay wall and oak sheet piles	144	10.2	17	20.9	3,015	$4,900	$34.02	$1.62
	Steel sheet piling	265	----	22	25	6,625	6,365	24.02	.96
June, 1908, to May, 1909	East Crib Dam	402	22	21	21.5	8,653	20,665	51.40	2.39
June, 1908, to February, 1909	North Crib Dam—timber	432	13.5	23	20.9	9,041	16,697	38.65	1.85
November to December, 1908	Junction Dam—clay wall	30	----	18	16.6	449	1,251	41.70	2.78
December, 1907, to January, 1909	North Cofferdam—clay wall	1,313	8.6	14	11.8	15,460	14,396	10.96	.93
June, 1908, to October, 1909	N. W. Cofferdam—clay wall	539	6.7	13	14.4	7,709	10,680	19.79	1.38
March, 1908, to January, 1909	West Cofferdam—clay wall	258	8	10	12.8	3,298	3,208	12.43	.97
March, 1908, to April, 1908	S. W. Cofferdam—clay wall	179	30	29	30.3	5,228	3,456	19.31	.66
November, 1909, to May, 1910	Supplementary Work—								
	Lally and S. W. Dam:								
	Fir sheet piling and tie rods	351	----	----	26.5	9,298	4,297	12.24	----
	Stockramming leak	100	----	----	-----	-------	375	------	----
	Grand total	------	----	----	-----	68,776	$86,290	------	$1.25

The northwest dam cost $1.38 because of the water troubles and burden of stockramming leaks, and because of the high cost of summer delivered clay and its subsequent rehandling. Could this section have been built in the winter time, its cost might have been much less.

The short junction dam at $2.78 carries a large burden of overhead expense, and it is unfair to draw comparisons of cost. It is possible that steel piling could have been used at a saving in cost.

The southeast dam at $1.62 is high, because of the elaborate sheathing employed; no especial difficulties being encountered in its construction.

Cost of Crib Dams. The crib dams are relatively expensive, because of the amount of material used in their construction and the difficulty in getting the cribs in good contact with the rock bottom. The north dam cost $1.85 per square foot against $2.39 for the east dam, the difference being due entirely to the larger quantity of excavation necessary for the latter section.

Steel Piling. The cost for the heaviest (40-pound) steel piling driven through 25 feet of hard driving (boulders, gravel and hardpan) was only 96 cents per square foot. This makes it a formidable rival of the clay puddle wall. Its use at this locality was an experiment and, had its possibilities been as well known then as now, several other sections of dam might have been built of steel sheet piling at a considerable saving in time and probably in cost.

EFFICIENCY—LEAKAGE INTO PIT.

The efficiency of the different sections of cofferdam has been first class. The only leaks were a small one under or through the east crib dam, and another, amounting to enough to fill a 3-inch pipe, under the steel piling of the southeast dam, where one piece of piling evidently struck a boulder. The only money paid out for maintenance by the contractors was in connection with the latter leak, when the masonry contractor bore the expense of a few days stockramming, amounting to about $346.00.

A leak of considerable size developed through a rock seam under the southwest dam. This leak probably occasioned 75 per cent of the required pumping and both the contractor for excavation and the contractor for masonry spent considerable money in unsuccessful attempts to stop it. This leak is not chargeable to inefficiency of cofferdam, however.

PUMPING—QUANTITY AND COST.

The *pumping plant* was installed by contractor for excavation and the pit first unwatered on September 26, 1909. At the expiration of his contract the plant was purchased by the masonry contractors and operated by them directly until June 19, 1914, and as subcontractors up to August 1, at which time the pumping was taken over by the United States.

The battery of pumps originally installed was as follows:

One 10-inch centrifugal with 100-horsepower motor
One 8-inch centrifugal with 85-horsepower motor
One 6-inch centrifugal with 50-horsepower motor
One 5-inch centrifugal with 20-horsepower motor, and
One 4-inch centrifugal with 15-horsepower motor

The maximum battery required at any one time consisted of the four latter pumps, the 10-inch being a reserve unit for emergency.

The *volume of pumping* varied from a minimum daily average of about 850 thousand gallons in winter, while the adjoining canal was unwatered, to a maximum daily average of about 3,000 thousand gallons during the summer. The maximum for any one day was about 4,000 thousand gallons.

Cost of Pumping. Under the contract for excavation there was pumped (during 757 days, between September 26, 1909, and October 23, 1911), 1,242,628 thousand gallons, at the following cost to contractor:

Labor		$11,428
Electric power (at 1 cent per k. w. hour)		6,975
Fuel		403
Supplies		398
Repairs		147
Overhead charges:		
Installing plant	$314	
Interest and depreciation	2,151	
		2,465
Total cost		$21,816

or $0.0176 per thousand gallons, or $28.90 per calendar day.

Under the contract for lock masonry, the pumping during 858 days (October 23, 1911, to March 1, 1914) amounted to 1,094,760 thousand gallons, and cost the contractor as follows:

Labor		$12,208
Electric power (at 1 cent per k. w. hour)		8,221
Supplies, fuel and repairs		2,052
Overhead charges:		
Interest and depreciation	$1,012	
Dismantling (assumed)	300	
		1,312
Total cost		$23,793

or $0.0217 per thousand gallons, or $27.85 per calendar day.

Triton Electroplating Plant at Washington Barracks, D. C.

BY

Lieut. R. W. CRAWFORD,
Corps of Engineers.

INTRODUCTORY.

Trinitrotoluol, or "triton," as it is usually termed, has certain properties which have caused its adoption by the United States, and almost all foreign governments, as the standard military demolition explosive. The more important of these are: that it can be handled and transported with absolute safety; is insensitive to shock, and does not form sensitive compounds by combination with the metals.

It is manufactured by acting on toluene (a by-product in the manufacture of illuminating gas) with a mixture of nitric and sulphuric acids. The product is a fine crystalline powder, slightly yellow if nearly pure, assuming a brownish tinge as the impurities increase.

The explosive is in the market in two forms: as a crystalline powder, and in cast blocks formed by melting the powder and casting it into any desired shape. In the latter form it is too insensitive to be detonated by any primer which it is considered safe to carry in the demolition equipment. For this reason the crystalline form was early adopted for demolition purposes.

Powdered triton when loose is inconvenient to handle; it absorbs moisture readily, with a consequent loss of sensitiveness, and it lacks density, which affects its "cutting" power. To remedy this effect of low density, advantage is taken of the fact that the crystals can be made to cohere under pressure, with the result that blocks of even greater density than that of castings of the same explosive may be formed. The sensitiveness of the explosive decreases to a considerable extent as the degree of compression is increased, but not to the prohibitive stage that it does when melted and cast.

As a result of experiments undertaken to determine the maximum density at which triton can be detonated with certainty when using ordinary primers, a density between 1.44 and 1.48 has been decided upon. (The average density of blocks now being purchased by the Engineer Department for the service is about 1.468, obtained by a pressure of 10,000 pounds per square inch.)

Since any space between a block of explosive and the object to be cut reduces the effect of the explosive, it follows that a rectangular block is best adapted to cut an object with plane surfaces and a cylindrical block, or stick, when the explosive is to be placed in bored holes. Consequently, it was decided to purchase triton in both shapes. The rectangular blocks are about 1¾″×1¾″ ×3 3-16″, and weigh approximately ½ pound avoirdupois, while the cylindrical sticks are about 1¾ inches in diameter by 3¼ inches long and weigh about .39 pound, avoirdupois. The blocks and sticks are bored at one end along their longer axis to receive the caps. A third form, now under consideration, is to be exactly similar to the rectangular blocks above described, except that the axial hole will extend entirely through the block. Such blocks could be strung on detonating cord (*cordeau detonant*) like beads, and be hung around the object to be cut.

Crystalline triton in paper bag containers has been purchased at least once for demolition purposes. It has the advantage of being easy to detonate, but has all of the disadvantages of powdered triton previously pointed out, with the additional and obvious objection to the paper bag. This form will probably never be used for demolition purposes, except when the compressed forms can not be obtained in sufficient quantities.

The word "triton," when used hereafter in this article, will refer to triton in the form of compressed blocks.

Though the insensitiveness of triton to shock is an advantage, it is also a disadvantage in that it is not conducive to careful handling and, as the blocks are quite friable, it was soon evident that some form of protective covering to decrease their liability to break up was a necessity. In addition, it was very desirable that this covering be in the nature of a waterproof coat, in order that the blocks might not absorb too much moisture and so become difficult, if not impossible, of detonation.

It was known that the Germans copper-plated their blocks, but inquiry disclosed no firm in this country willing to attempt the operation at a cost of less than $2.00 per pound. A sub-

stitute was sought. The edges of the blocks were rounded off, a coating of paraffin was applied and each block was placed in a telescopic paper box, made of hard glazed paper. A short trial proved that this solution of the problem was not entirely satisfactory, for the following reasons:

1. In case of shock or rough handling neither the paper boxes nor the paraffin coverings were strong enough to prevent breakage of the blocks;
2. The paraffin covering was easily broken, thus permitting the blocks to absorb moisture with consequent loss of sensitiveness;
3. The paper boxes were bulky, and consequently reduced the amount of triton that could be carried in the demolition packs.

During the early part of 1915 the matter was again taken up by the Engineer Depot at Washington Barracks, D. C., and after a short study it was decided that the German practice was the best possible method and ought to be adopted by the United States. Since the quotations of private firms were exorbitant, it was further decided that the plating should be undertaken by the Engineer Depot, and a small plant, more or less experimental, was installed in the basement of the Depot. This plant is referred to hereafter as the "Old Plant."

GENERAL PRINCIPLES INVOLVED IN ELECTROPLATING.

The object which is to receive the coating of metal is employed as the cathode (negative terminal) and immersed in a solution of a salt of this metal. The anode (positive terminal) may either be soluble and consist of the metal to be deposited or it may be inert; the object of the former arrangement is to get as much metal dissolved from the anode as is deposited upon the cathode during the plating process; on the other hand, if an inert anode is used it is necessary to replenish the solution at intervals during the operation, in order to make up for the metal lost by deposition on the cathode.

In an electroplating bath in which the anode consists of the same metal as that which is plated out on the cathode, the electrochemical reaction at the cathode is the reverse of that at the anode, so that the reaction itself requires no electromotive force (neglecting some very small and negligible losses). The e. m. f. applied at the terminals of the bath is therefore lost in overcoming the ohmic resistance of the circuit. If an inert anode, such as platinum, is used in a copper sulphate solution (for copper plating), oxygen

is evolved, sulphuric acid is formed at the anode, while the copper is plated out on the cathode. The voltage applied at the electrodes in this case is equal to that required to overcome the ohmic resistance of the circuit plus the decomposition voltage of the solution. The former is small in a properly designed plant. The latter depends upon the solution, but rarely exceeds a few volts. As a consequence, the voltage applied at the electrodes of a plating bath is relatively low, generally falling between a fraction of 1 volt and 6 volts. But, while electrolytic generators are low voltage machines, they must supply high currents, as the rate of metal deposition is very nearly proportional to the current. From theoretical considerations, one might conclude that the higher the current the more rapidly will the process of electroplating proceed. This is true up to a certain point, beyond which practical difficulties are encountered, since for every bath there is a very definite critical current density. A current greater than this critical value results in the release of hydrogen at the cathode. As a consequence, the metal is deposited as separate crystals with little coherence. However, by rotating the cathode or agitating the solution so as to "wipe off" these hydrogen bubbles, it is possible to use a higher current density and still obtain good results.

THE OLD PLANT.

The power for the old plant was furnished by a 3-volt, 250-ampere motor generator set. The generator was driven by a single-phase repulsion type induction motor taking power from the city alternating current mains. To save the cost of an exciter set for the generator, the field current was obtained from the nearby 550-volt street car service lines. The excess voltage was wasted through four or five 32-candlepower incandescent lamps placed in series with the generator field.

Two lead-lined tanks, each holding 40 triton blocks, were connected in series across the generator terminals. Five ¾-inch hollow brass rods were placed longitudinally over each tank. Three of these connected in parallel supported the anodes, while the other two, also connected in parallel, supported the cathodes. The blocks of triton were therefore suspended between rows of copper plates and received their deposit from two sides. The anodes consisted of pure copper plates, 12 inches long, suspended from the rods by means of copper hooks. The cathodes were the triton blocks supported by means of brass hooks. The current entered

one tank through three rods, passed through the copper hooks to the copper plates, thence through the solution to the triton blocks and out by way of the second set of brass hooks and rods to the second tank in which the circuit was similar. Due to the poor contact between the rods and hooks, it was found necessary to weight the latter in order to reduce the voltage drop at these points.

The operations of plating were carried out as follows: The triton was unpacked at the work table and a brass hook, after being dipped in paraffin, inserted in the primer hole. The blocks were then set on the work table until the paraffin hardened, when they were given a coating of graphite dissolved in alcohol. This coating was applied in order to make the surfaces of the blocks "conducting." Otherwise, the current would pass directly to the brass supporting hook and leave its deposit of copper there.

The full capacity of the generator could never be counted upon, so that a current of about 1.25 amperes per block was the average obtained. In two hours and a half this formed a thin deposit of copper sufficient to hold a block intact when dropped from a height of from 3 to 4 feet onto a concrete floor. During the plating process it was necessary to give constant attention to the surface of the blocks, since the numerous handlings were very liable to cause grease spots on the graphite and render them non-conducting. When such spots developed it was necessary to remove the block from the solution and wash the grease off with alcohol. At the expiration of two and one-half hours the circuit was broken and the blocks removed, washed, and the tanks refilled. The time required for these operations was about one hour.

The output of this plant was about 160 blocks per day of eight hours. Two shifts of two men each were usually employed. The cost of plating per block can not be exactly determined, due to the lack of reliable figures, but that shown in the comparison table (pages 297-298) is believed to be fairly accurate.

As mentioned previously, this plant was more or less experimental and it was expected to develop faults. Certainly faults did develop, among which the more important were as follows:

1. The voltage of the street car service lines varied so that it was impossible to maintain constant generator voltage;

2. The generator would not carry its rated load, and it was found impossible to prevent the brushes from wearing grooves in the commutator;

3. The soldered joints in the lead lining of the tanks leaked and

could not be permanently repaired, due to the acid in the electrolyte;

4. The contacts between the hooks and the supporting rods were very poor. Both rods were circular in cross section and, consequently, there was frequently but one point of contact. At times a voltage drop of 80 per cent of the total was found at such points. Part of this was undoubtedly due to dirty and corroded rods. Excessive voltage drops also developed at other points;

5. The graphite dust, used to coat the triton blocks, was of too high resistance. Moreover, the blocks required constant attention during the plating process and frequent washing in alcohol, which was bothersome and expensive;

6. The output of the plant was far below what was required, to say nothing of a total absence of any reserve capacity;

7. There were frequent "shut-downs" for repairs;

8. The generator and tanks were idle for one hour between runs;

9. The system of handling the blocks was clumsy;

10. The cost of plating per block was considerably greater than the cost would be in an efficient plant.

Due to the above defects, Capt. J. G. B. Lampert, Corps of Engineers, was instructed to make a thorough study of the subject of plating triton, as well as an investigation concerning possible substitutes for electroplating. After visits to the more modern electroplating establishments and discussing the subject with numerous engineers, among them Mr. Thomas Edison, Captain Lampert reported that electroplating was, so far as could be ascertained, the only suitable method of treating triton, and that of the various elements, copper was the most satisfactory for the purpose. As a result of this report, he was ordered to design and install a plant having a maximum capacity of 10,000 blocks per week. The plant described in the following pages is the result of his work.

THE NEW PLANT.

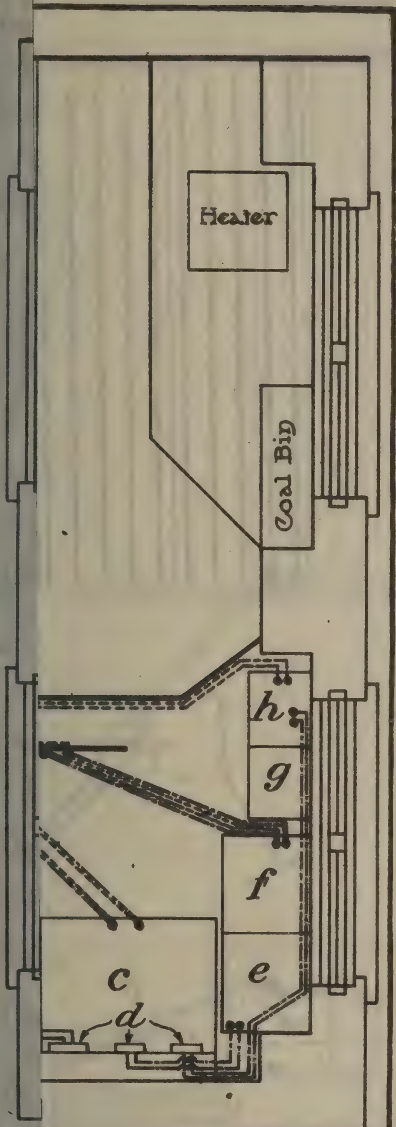
The outstanding feature of the design of this plant is the exceptional efforts made to cut down unnecessary voltage drops. With 5 volts to start with at the generator and with a maximum current of 1,000 amperes to contend with, it is evident that careful designing was necessary. The resistance of soldered joints, contact resistance of switches, and the resistances at other points usually neglected in ordinary design, had to be worked out most carefully for this plant. Offsetting this was the ease of insulating the various parts. With such a low voltage, a crow-bar placed across all the rods on one tank failed to put more than 5 per cent

load on the generator. A "short" on such a machine is almost impossible.

Considerable time was also spent in working out a systematic scheme for handling the blocks economically. It is believed that the results show, on a small scale at least, what careful planning can accomplish in this direction.

The general lay-out of this plant is shown in Fig. 1 and a view of the interior of the tank room in Fig. 2. The plating room contains eight solution tanks, two wash tanks with drying racks and a small packing table. The solution tanks are arranged in sets of two, so as to leave a working space of about 2 feet between sets. (End and plan views of a tank are shown in Fig. 3.) The tanks are of wood, about 10 feet long, 3 feet wide and 1 foot deep, and are lined with sheet lead, similar to that in the old plant, except that a better grade and thinner sheet is used and the corners are folded instead of being cut and soldered. This eliminated the old trouble of acid working through the soldered joints and resulted in cheaper and better tanks. Since, as will be explained later, mercury is apt to fall into the tanks, it became necessary to investigate the action of mercury on lead. It was found that a drop placed on a sheet of lead would amalgamate it in a very short time, causing perforations. Several protective coatings were tried, and of these asphaltum pitch appeared to be best and was therefore used.

As in the old plant, the anodes and cathodes are supported from five hollow brass rods running longitudinally along the tank. Large rods (1-inch) are used in order to cut down the voltage drop. The two outer and the central rods in each tank are connected in parallel and support the anodes, while the other two, also connected in parallel, carry the cathodes. The tanks are arranged electrically in sets of four in parallel (see Figs. 1 and 2), the lead from the anodes being carried to a single pole, double-throw switch at the rear of the room and that from the cathodes to a similar switch located in front of the tanks. The switches were separated in order to use shorter lengths of the low-resistance cable. The generator leads are carried overhead to these switches. It will be noted that the electrical connections are such that one set of tanks may be charged while the other set is being emptied and filled. In order to reduce the voltage drop between the leads and



KEY:

a: Sa
b: W
c: 5
d: Sh
e: 3
f: 3v
g: 2/
h: 1M
i: Sw

AN

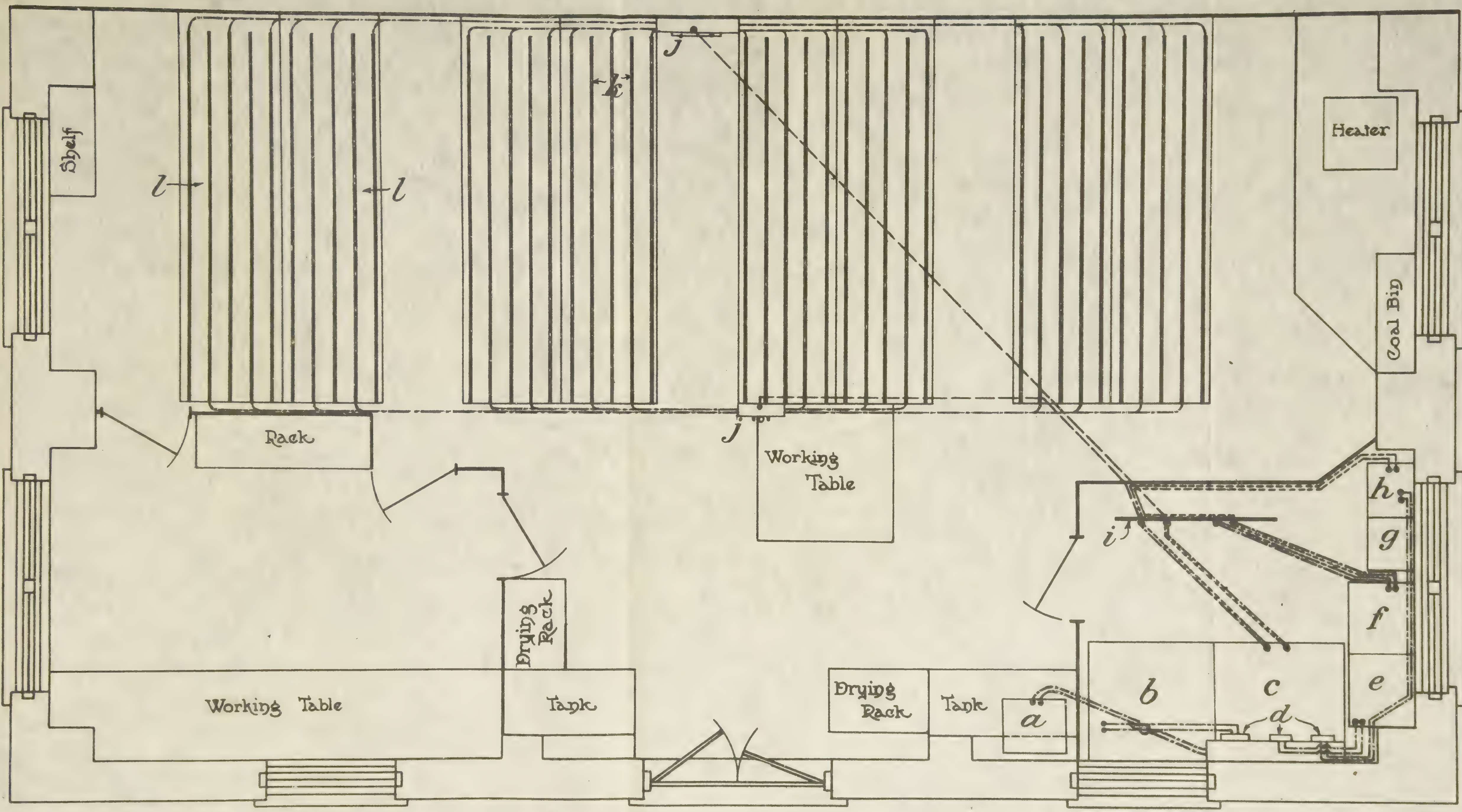
ATING PLANT

acks, D.C.

1 ft.

5 6 7 8 FT.

FIG. 1.



KEY:

--------------- Exciter circuits
— — — — — — Suspended power conductor
—·—·—·—·— Power conductors

a: Suspended Transformer, 220 volts, 60 cycles
b: Wagner 10 H.P. single phase motor } Motor generator
c: 5 volts, 1000 amps. generator } set
d: Starting boxes
e: 3 H.P. single phase motor } Reserve motor } Old
f: 3 volts, 250 amps. generator } generator set } set
g: 2 H.P. single phase motor } Exciter motor
h: 1 KW generator, 110 volts } generator set
i: Switch board
j: Single pole, double throw switch
k: Brass tubing
l: Tanks filled with a solution of the following proportions:
- 1 gal. water
- 26 oz. sulphate of copper
- 3¼ oz. sulphuric acid
- 1 oz. ground alum

FLOOR PLAN

TRITON ELECTROPLATING PLANT

Washington Barracks, D.C.

Scale: $\frac{1}{4}$ in. = 1 ft.

→ N   1 0 1 2 3 4 5 6 7 8 FT.

FIG. 1.

brass tubes, the former are inserted in the ends of the tubes, and the joints soldered and wiped (Fig. 3).

The cathodes are, of course, the triton blocks. The graphite surface, as mentioned above, was not satisfactory, due to its relatively high resistance and, consequently, a coating of copper dust was tried and found highly satisfactory. While somewhat more expensive it is easily applied, has low resistance, and requires little attention if care is taken. Extensive investigations were carried on, and experiments made with various mixtures and methods of spraying the blocks with a liquid conducting coating. None of these

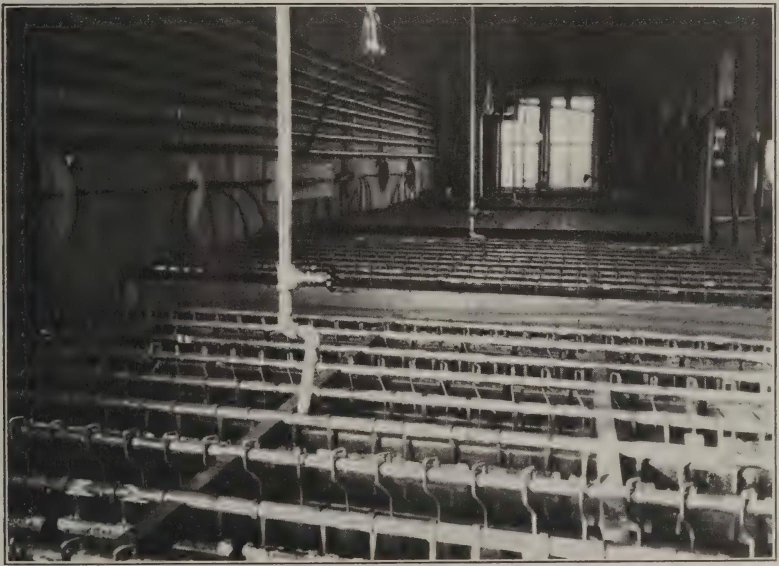
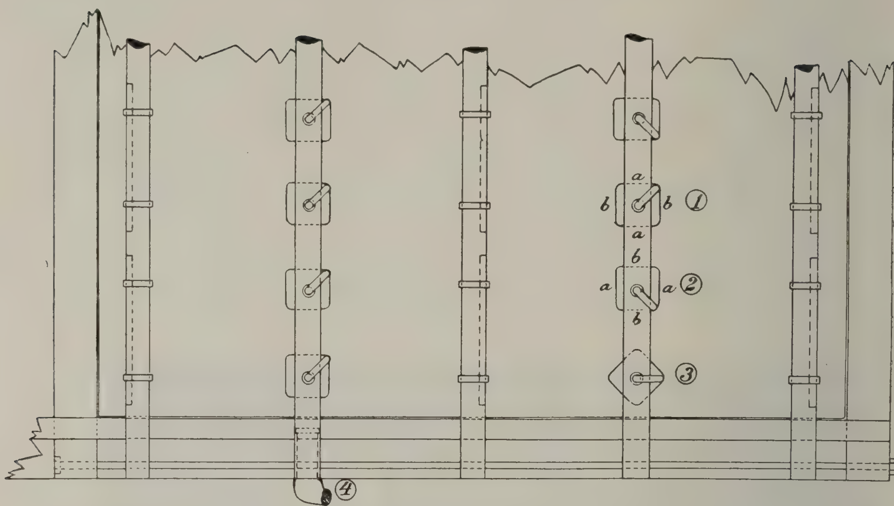


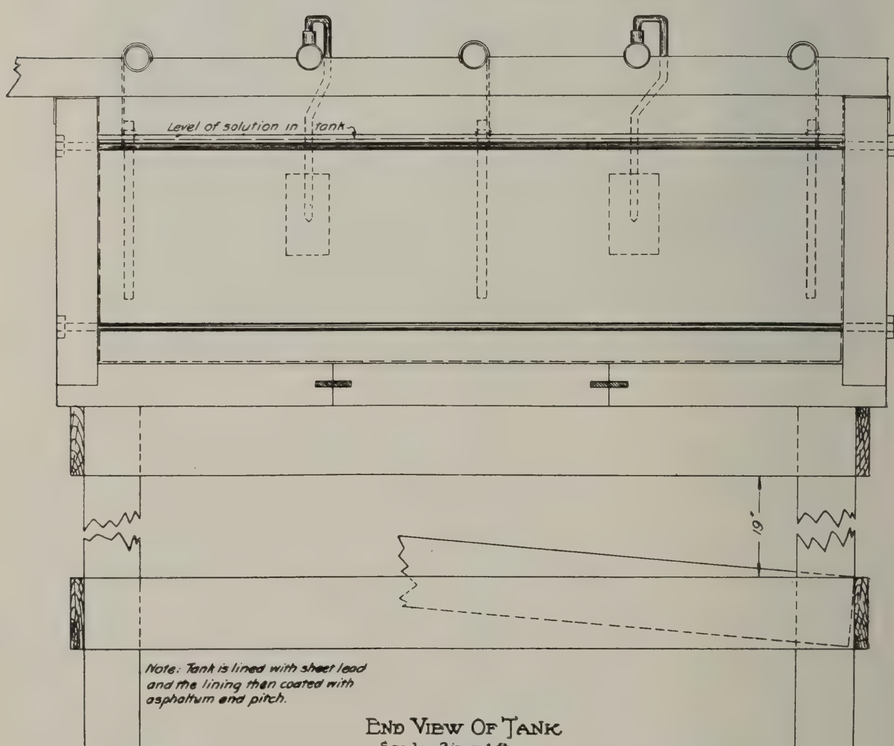
Fig. 2. General View of Plating Room.

were as satisfactory or simple as merely rubbing the dust into the surface by hand.

Another change made was the means of suspending the blocks from the brass rods. After several experiments, the system was devised which now in use and is shown in Fig. 3. A piece of ½-inch copper rod, about ½ inch long, is bored to form a cup 5-16 inch deep at one end and the other end shaped to fit the 1-inch brass rods. This copper cup is then soldered in a vertical position to the rod and a drop of mercury is placed in the cup. The brass hooks are made ?-shaped and hung in these cups, thus reducing the voltage drop at these points to an inappreciable



PLAN OF PART OF ELECTROLYTE TANK



END VIEW OF TANK
Scale 3in. = 1ft.

Fig. 3.

amount and eliminating the weights required in the old plant. The reason for making the hooks in this shope is two-fold: first, it places both faces of the block equidistant from the two sets of anodes and, second, allows the blocks to be turned through an angle of 90 degrees about a vertical axis, thus exposing all faces to the same average current, and so securing an even coating. The procedure is indicated in Fig. 3, showing the block in the two usual positions.

Improvements were also made in the method of suspending the anodes. Where an **S**-shaped hook of circular cross-section was previously used, a ʔ-shaped hook of rectangular cross-section, riveted to the copper plates, is now used. This gives a more intimate connection between the plates and hooks, and provides larger contact area between the rod and hooks. Since, in the old plant, the plates were habitually destroyed, due to the copper dissolving from the middle of the plate and the bottom portion falling off, 6-inch anodes are used as compared to 12-inch in the old plant. This has effected a considerable saving in the amount of copper used per block, as well as reducing the investment in idle copper. The tanks were made correspondingly shallower, so that a further saving in their cost and in the cost of the solution resulted.

The wash tanks consist merely of rectangular wooden tanks with running water. The drying racks consist of inclined ways, for the reception of wooden trays with perforated bottoms. While simple, these tanks, trays, and racks have resulted in increased efficiency besides effecting an appreciable saving in the amount of labor previously devoted to rinsing and drying the blocks.

The packing table is simply a flat top table, near the center of the room and in front of the plating tanks. A frame constructed to hold two boxes is erected on one end. A drawer for corks and a receptacle for brass hooks complete the equipment.

For various reasons, it was considered advisable to separate the generator room from the tank room. Here are installed the main generating unit, the reserve unit and the exciter set. All of these are driven by single-phase induction motors. The starting boxes are grouped on a panel above the main unit. The distribution panel and generator switchboards are placed against the partition on the west side of the room. All wiring between the generators and switchboards is placed in conduits beneath the floor.

The main unit is a 5-volt, 1,000-ampere motor generator set. The reserve unit is the motor generator set from the old plant. It is rarely, if ever, used, but in case of necessity would probably carry two tanks. The generator field current is supplied by an exciter set consisting of a 1-kilowatt, 110-volt motor-generator set. The voltage of the electrolytic generator is varied by manipulating rheostats placed in both the generator and exciter fields. Suitable connections are provided for exciting the field of the old set and for throwing its power onto the distribution panel.

When the plant was first started the critical current density per block was 1.5 amperes. By installing a small air compressor and forcing air through perforated lead tubes placed at the bottom of each tank, it has been possible to double this and thereby to reduce the time required for plating to half.

The various operations performed on the blocks may be grouped under the following heads:

1. Preparing the blocks—
    - *a.* Inserting the brass hooks;
    - *b.* Coating blocks with paraffin;
    - *c.* Dusting with powdered copper;
2. Loading the tanks;
3. Plating—
    - *a.* Regulating current;
    - *b.* Shifting blocks 90 degrees about vertical axis at intervals;
4. Operations after plating—
    - *a.* Removing;
    - *b.* Washing;
    - *c.* Drying;
5. Packing the blocks—
    - *a.* Removing hooks;
    - *b.* Inserting corks;
    - *c.* Packing in boxes;
    - *d.* Storing.

Four men are employed for each of three shifts, the plant running continuously.

The actual plating process requires very little attention, since all that is necessary is to manipulate the field rheostats until the voltage which will produce the desired current is obtained, and then occasionally to shift the block hooks 90 degrees by running the hand along them. The four men are therefore continuously

engaged either in removing a charge or in preparing a new one for one set of four tanks while the other set is in operation.

The triton is received at the depot in boxes of 108 blocks. It is unpacked in the preparing room and the blocks placed at the two ends of the work table. One or two workmen then insert the brass hooks in the fuse holes. This requires dipping the straight end of the hook into a basin of melted paraffin which rests on a small gas burner in front of each man, and then pressing the hook down into the fuse hole. When the paraffin is hard it is scraped from the hook at its junction with the block, since otherwise it would insulate the rod and break the circuit through the block.

The other workmen apply the copper dust with the hands incased in rubber gloves to prevent the fingers making grease spots upon the dusted surface. Ordinarily, these men wear respirators to keep the dust from the lungs and nose. Three men can dust blocks about as fast as one can insert hooks.

After dusting, the blocks are hung in small wooden hand racks holding 12 blocks. A frame in the center of the wood table will hold 6 of these racks. They are removed as filled and placed in a wall rack in the rear of the room. It will be seen that the blocks pass from both ends of the work table towards the center.

The loading of the tanks is habitually done by one man. The hand racks are removed from the wall rack and placed in a frame on top of a two-wheeled truck, which is of such a size that it may be run between the tanks. This truck will carry 6 hand racks, a total of 72 blocks. Lifting a rack by the handle provided with the left hand, the workman takes one block at a time from this rack and engages the hook in the mercury cup, thus suspending the block in the solution. One tank will hold 70 blocks, 35 per rod, and consequently the fact that two blocks finally remain on the truck assures the workmen that he has overlooked no cups.

After the four tanks of one set are filled and the other set is charged, the double-throw switches are thrown over and a current of 840 amperes passed through the new charge for a period of two hours. This corresponds to a current of $\frac{840}{4\times70}$, or 3.0 amperes per block. Several times during the plating period a man passes along the tanks and rotates the blocks 90 degrees, as explained previously.

In emptying the tanks, a drain box is placed on the truck and the blocks removed by hand and placed therein. When full,

this box is taken to one of the sinks, where it is placed in running water until all the acid is washed off. It is then placed in the drying rack, where it remains until all the blocks are thoroughly dry.

The drain boxes are next removed from the racks and placed on a frame on one end of the work table. On the opposite side of the table a packing box is placed on a similar frame. One workman pulls the hooks from the blocks, throwing them into a receptacle provided in the top of the table, and places the blocks to one side. A second workman picks up these blocks, dips a small cork in paraffin and inserts it in the fuse hole, and then places the blocks in the packing box.

The output of the plant, when working properly, averages 8 boxes (864 blocks) per shift of 8 hours, or 2,592 blocks per day. It is believed that this can be increased to 30 boxes (3,240 blocks) by increasing each shift to 5 men.

It will be seen from the preceding that though the plant was originally designed for a weekly output of 10,000 blocks, the various labor-saving devices and the double tank arrangement has very nearly doubled this. Working seven days a week, the output (under ideal conditions) would be about 22,500 blocks. This, however, is not the higher limit; the various devices to reduce voltage drop have worked out so successfully that the present tank arrangement could be duplicated and two sets run in series, thus doubling the output again. This relatively great reserve capacity was secured at small additional expense. In an emergency it is believed that the additional tanks, etc., required to secure this additional capacity could be installed in less time than it would take to get the triton.

The cost data for the two plants set forth in the following tables, while not exact, is believed to be nearly correct. As there set forth, it shows the cost of plating when everything is running smoothly and continuously. Actually, the plants run intermittently, depending upon the demand and supply of triton. When the plant shuts down the men are diverted to other work, so that the only expense is the depreciation on the plant.

The new plant, which cost about $3,000, should last indefinitely with the exception of the generator, which will probably require a new commutator in five years. The physical depreciation in the first five years should not exceed $500.

COST DATA.

Old Plant.

Plating 160 blocks (output per day of 8 hours).

Materials—		
Copper sulphate, .6 lb. per day at \$0.105 lb.	\$0.063	
Alum, .05 lb. per day at \$0.08 lb.	.004	
H_2SO_4=.011 gal. per day at \$2.00 gal.	.022	
Copper=5 lbs. per day+1 lb. waste, at \$0.365 per lb.	2.190	
Alcohol=1 qt. per day at \$0.75	.750	
Graphite=⅜ lb. per shift at \$0.64 per lb.	.240	
Paraffin=¾ lb. per shift at \$0.10 per lb.	.075	
Corks=1 per block at \$0.001 each	.160	
		\$3.504
Labor—		
Two men per shift		3.500
Power—		

Power (assume 60 per cent efficiency of generator and 60 per cent of motor—60×60=36 per cent combined efficiency).

$$\frac{100 \text{ amps.} \times 3.0 \text{ volts} \times 5.0 \text{ hours}}{1000 \times .36} = 4.16 \text{ kw. (motor).}$$

(Exciter) 1 amp. at 550 volts for 5.0 hours=2.75 kw.

Total, 6.91 kw. at \$0.06		.415
Total		\$7.419
Cost per block= $\frac{\$7.419}{160}$ =\$0.0463	\$0.0463	
Depreciation (assuming plant runs continuously)	.0041	
Total (per block)	\$0.0504	

New Plant.

Plating 864 blocks (output per day of 8 hours).

Materials—		
Copper sulphate=1.76 lbs. per day at \$0.105 per lb.	\$0.185	
Alum=.2 lb. per day at \$0.08 per lb.	.016	
H_2SO_4=.2 gal. per day at \$2.00 per gal.	.400	
Copper=13.4 lbs. per day+1.6 lb. waste at \$0.365 per lb.	5.475	
Copper dust=.8 lb. per day at \$1.40 per lb.	1.120	
Paraffin=4 lbs. per day at \$0.10 per lb.	.40	
Corks=1 per block at \$0.001 each	.864	
		\$8.460
Labor—		
Four men per shift		7.00
Power—		
From watt-meter readings, 24 kw. per day at \$0.06 per kw.		1.44
Total		\$16.900
Cost per block= $\frac{\$16.900}{864}$ =\$0.0196	\$0.0196	
Depreciation (plant running continuously)	.0004	
	\$0.02	

Improvement of Mississippi River from Winona to La Crosse

IN ACCORDANCE WITH THE 6-FOOT CHANNEL PROJECT ADOPTED BY CONGRESS, MARCH 2, 1907.

BY

Mr. W. A. THOMPSON,
Assistant Engineer,

AND

Mr. H. M. ANDERLY,
Junior Engineer.

The improvement of the Mississippi River in accordance with the adopted 6-foot project has been completed from Winona, Minn., to LaCrosse, Wis. Comparative maps accompany this report to show the effect of works constructed and improvements accomplished by open-channel regulation consisting of dredging, shore protections, spur, longitudinal and closing dams.

GENERAL DESCRIPTION.

The reach in question is 28½ miles long with a width of river valley between bluffs of approximately 3 miles. The bluffs are from 300 to 500 feet above low water and are composed of Potsdam sandstone in the lower levels with magnesian limestone outcrops on top.

The river bed is characterized by its sinuosities, bars and cutting banks, and is divided by many low wooded islands which are flooded to a depth of several feet during high stages, as the difference between high and low water is approximately 17 feet. Many lakes and marshes exist at all times.

The current varies from 1½ to 3 miles per hour with a mean slope of one-half of a foot per mile.

No records of borings taken in the bed of this section, which is entirely sand, are available. The probable depth can safely be placed at not less than 60 feet, as many piles have been driven 60 feet and no rock encountered.

Two bridges cross within the reach and there is also one at the

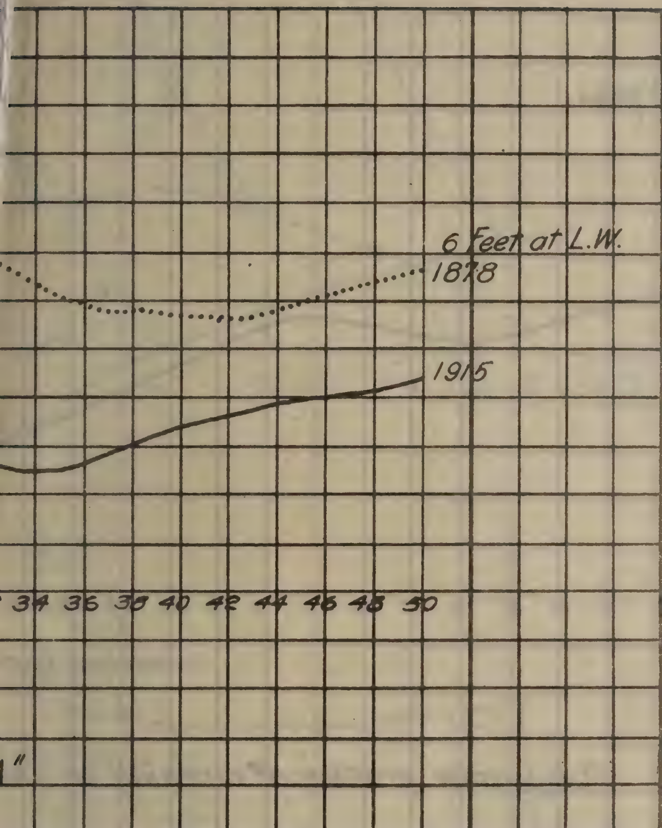


PLATE I

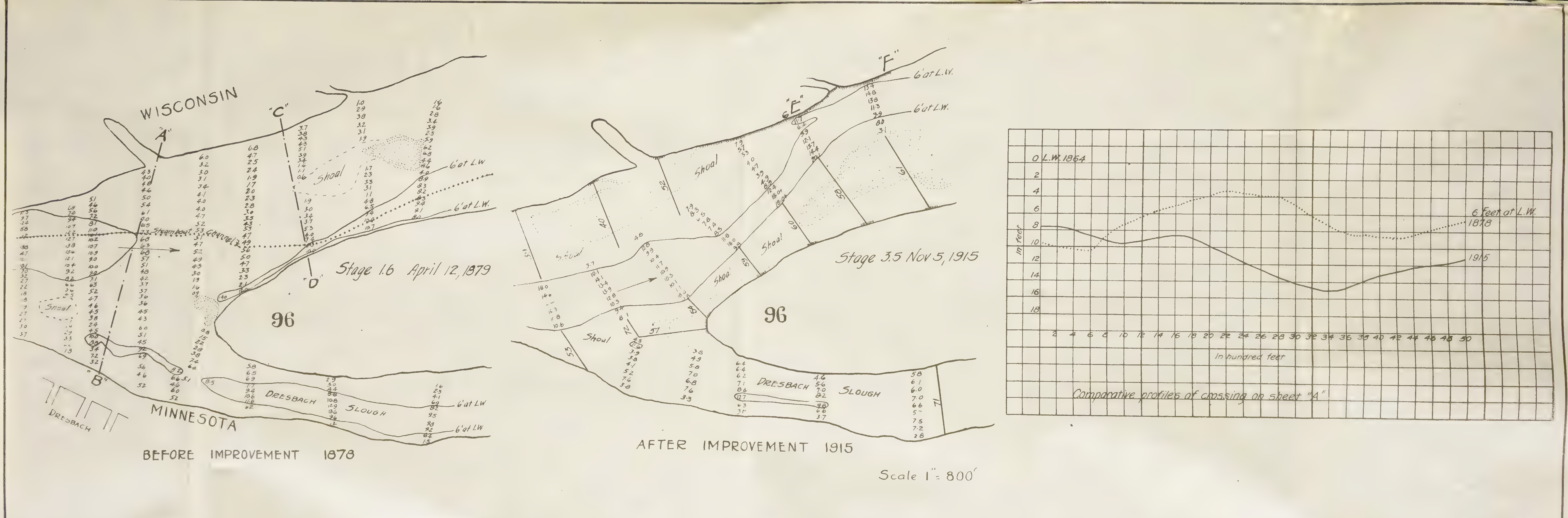

WISCONSIN
MINNESOTA
DRESBACH
"A"
"B"
"C"
"D"
Shoal
Steamboat Channel
6' at L.W.
96
Stage 1.6 April 12, 1879
DRESBACH SLOUGH
BEFORE IMPROVEMENT 1878
"E"
"F"
Stage 3.5 Nov 5, 1915
AFTER IMPROVEMENT 1915
Scale 1" = 800'
0 L.W. 1864
In feet
6 Feet at L.W.
1878
1915
In hundred feet
Comparative profiles of crossing on sheet "A"

PLATE I

head and one at the foot. One of these bridges has clear draw openings of 154 feet, one 160 feet and two 200 feet.

Three rivers enter this stretch, the Trempealeau, Black and LaCrosse. The Black is the only one of any considerable size and, as it is at the extreme lower end, its effect in conjunction with the other two small streams is negligible.

RIVER IN 1878, PRIOR TO IMPROVEMENT.

During the low water season it was impossible for the larger boats to proceed farther upstream than LaCrosse or Dresbach, due to the high sand bars where the maximum depth at low water was often not more than 2½ feet. There was a succession of twenty deep pools separated from each other by bars and similar to conditions as shown on Plate I. It is noted that in several subsequent years conditions were much worse than in 1878, perhaps attributable to the fact that in 1878, and for several years afterwards, low-water elevations were not well defined. The total length of indicated obstructions to a 6-foot channel was, however, 19,185 feet, or about 3½ miles.

It has been noted that depths shown on maps of 1878, taken from soundings made that year, could not be found by steamboats in 1901 and several other years, and no doubt could not have been found in 1878. The lines of soundings taken from about 600 to 1,000 feet apart may have missed the shoalest water, and besides steamboats could not follow the irregular course used in selecting the depths.

The only improvement work in this section done prior to 1878 was by the Chicago, Milwaukee & St. Paul Railroad Company before it built its bridge across the river, about 2 miles above LaCrosse. The river in the locality of the proposed bridge was divided into two nearly equal channels. In order to confine the principal flow and steamboat channel through its proposed draw near the Minnesota shore, and to obviate the necessity for two draw bridges, it built in 1875 and 1876 a closing dam across the chute east of Island 101, thereby confining the flow of water below a 4-foot stage to the west of the island and through the draw. This railroad company also riprapped the head and west side of Island 101 for a distance of 3,800 feet.

IMPROVEMENTS.

The limited amount of money available for early work undertaken by the Government (1878-1907) made it necessary to im-

prove those localities where the greatest difficulties to navigation had been experienced, as at LaCrosse, where the river threatened to take the course on the west side of Barrons Island and leave the city without a navigable channel.

Two closing dams were constructed and the river was forced to the LaCrosse side of the islands. Works similar to the above were proceeded with in the worst localities from year to year. The obstructions were partially removed and it was finally decided, in 1910, to start regulation at the head of the reach and proceed from the head down. From this time on the allotments were larger and work was carried on to better advantage. It may here

Beginning Construction of a Spur Dam during Summer.

be noted that up to 1907 the proposed channel contraction was to 800 feet, but subsequently to 625 feet.

One of the many obstructions is shown on Plate I, and is selected as it embodies all of the works of open-channel regulation used in this section and is typical of the twenty obstructions to navigation.

There were two deep pools, one along the Wisconsin shore opposite the village of Dresbach and the other along the east bank of Island 96, with a shallow bar between them, as shown between lines AB and CD on the plate. There is also a secondary arm (Dresbach Slough) along the Minnesota shore, and this diverted considerable water from the main channel. The obstructing bar between lines AB and CD was removed by the construction of

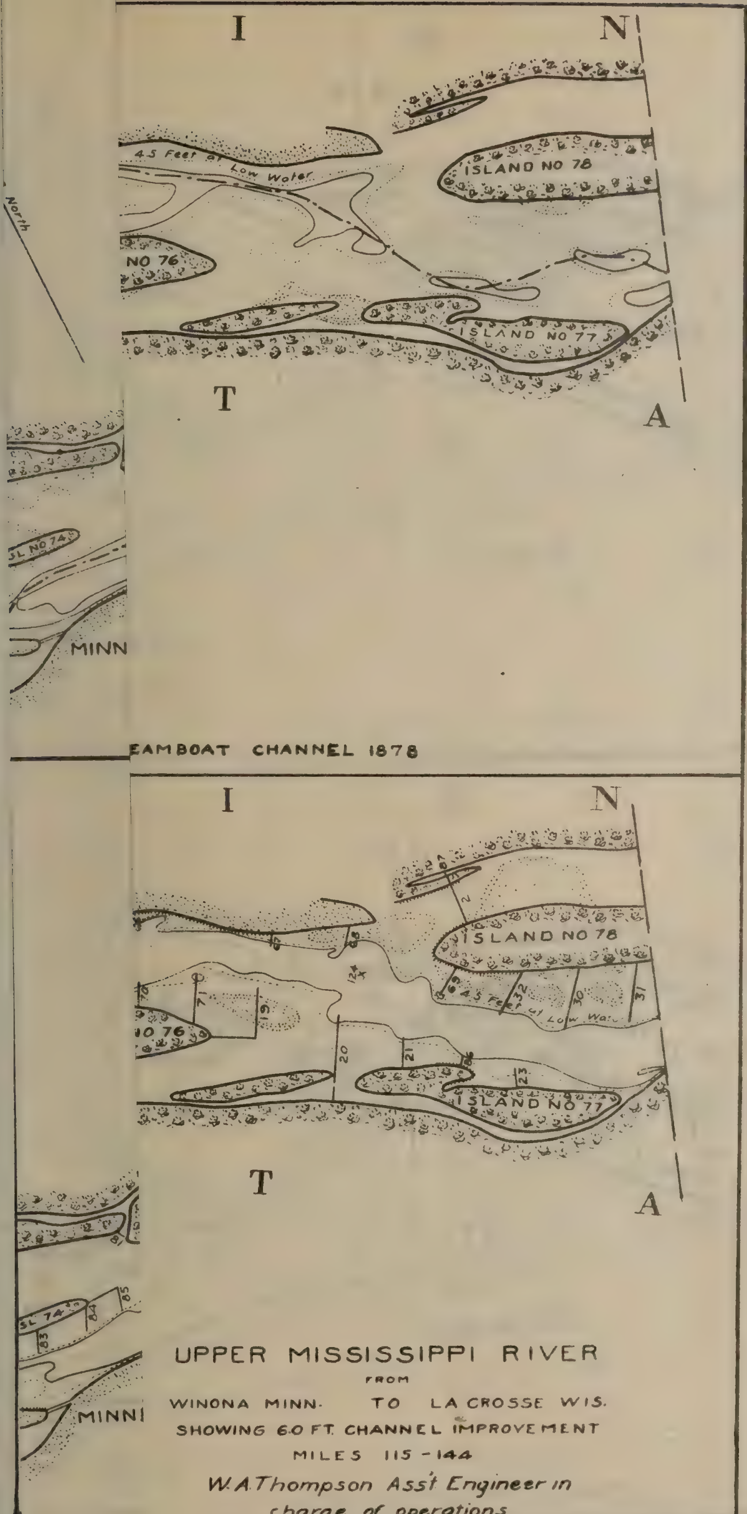
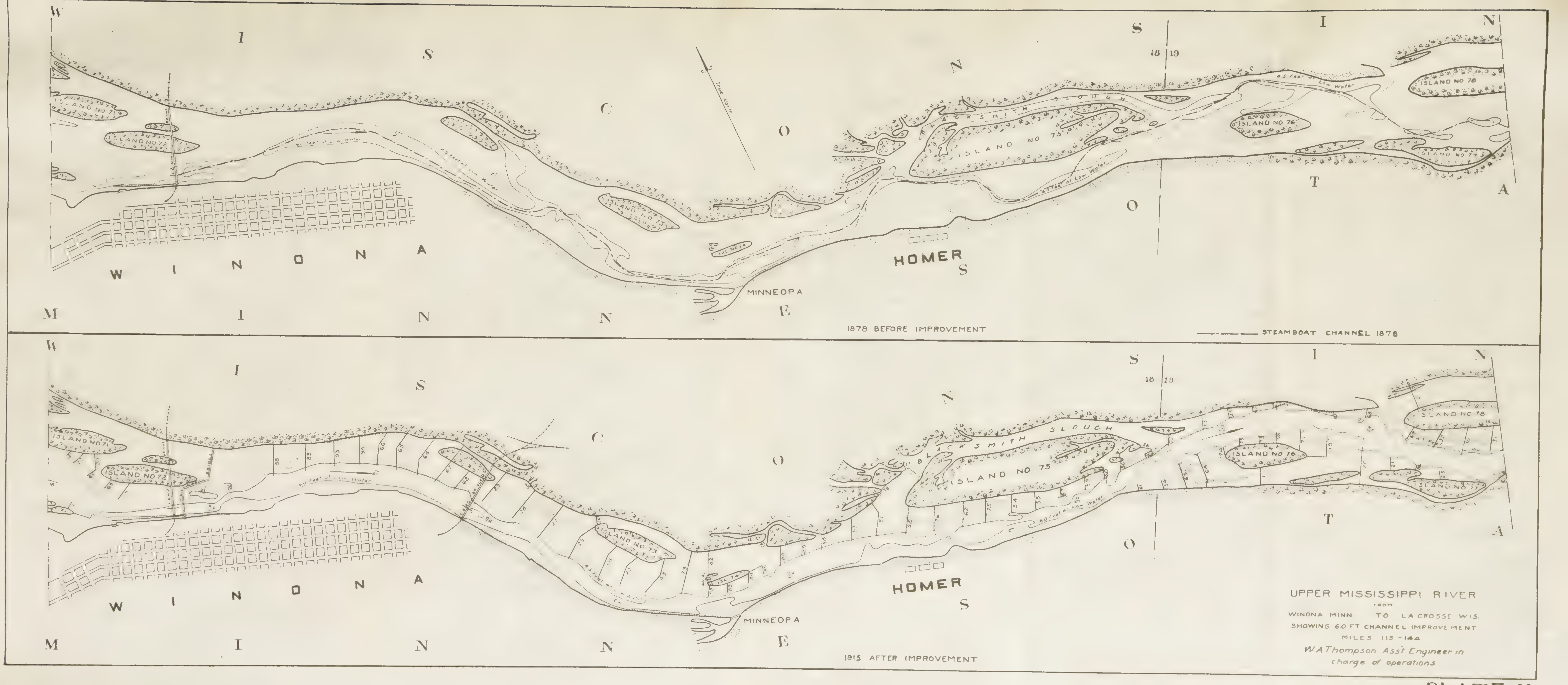
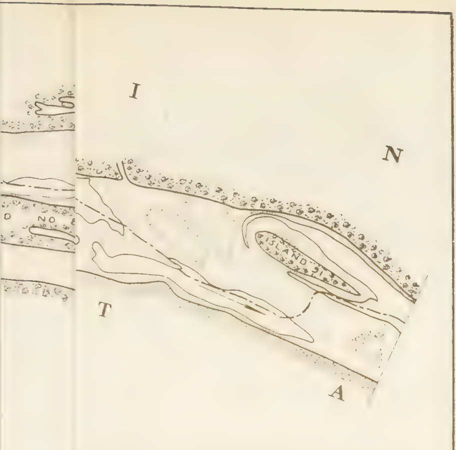

I
N
4.5 Feet at Low Water
ISLAND NO 78
North
NO 76
ISLAND NO 77
T
A
ISL NO 74
MINN
EAMBOAT CHANNEL 1878
I
N
ISLAND NO 78
4.5 Feet at Low Water
NO 76
ISLAND NO 77
T
A
ISL 74
MINN
UPPER MISSISSIPPI RIVER
FROM
WINONA MINN. TO LA CROSSE WIS.
SHOWING 6.0 FT. CHANNEL IMPROVEMENT
MILES 115 - 144
W. A. Thompson Ass't Engineer in charge of operations

PLATE II



WISCONSIN
MINNESOTA
WINONA
HOMER
MINNEOPA
ISLAND NO 72
ISLAND NO 73
ISLAND NO 75
ISLAND NO 76
ISLAND NO 77
ISLAND NO 78
BLACKSMITH SLOUGH
True North
18 | 19
1878 BEFORE IMPROVEMENT
STEAMBOAT CHANNEL 1878
1915 AFTER IMPROVEMENT
UPPER MISSISSIPPI RIVER
FROM
WINONA MINN. TO LA CROSSE WIS.
SHOWING 6.0 FT CHANNEL IMPROVEMENT
MILES 115 - 144
W. A Thompson Ass't Engineer in charge of operations

PLATE II



STEAMBOAT CHANNEL 1878

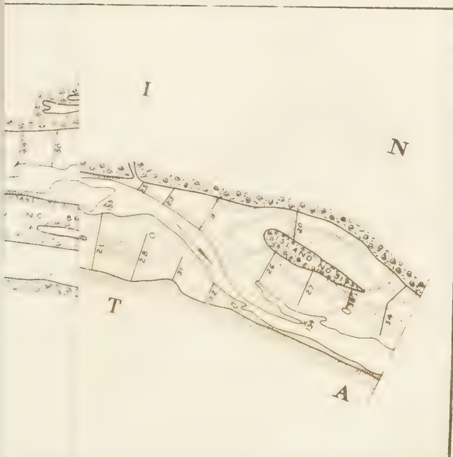
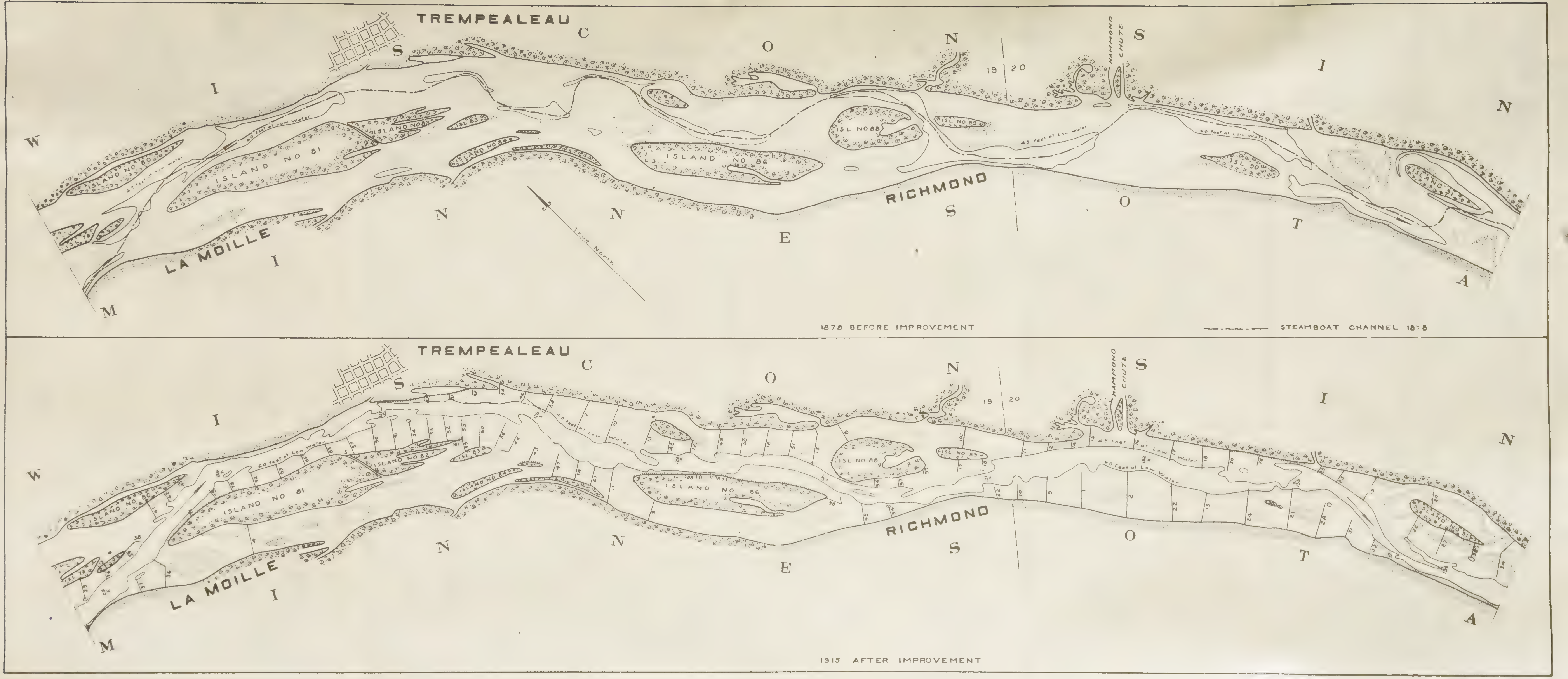


PLATE III



TREMPEALEAU
WISCONSIN
MINNESOTA
LA MOILLE
RICHMOND
HAMMOND CHUTE
ISLAND NO 80
ISLAND NO 81
ISLAND NO 82
ISL 83
ISLAND NO 84
ISLAND NO 86
ISL NO 88
ISL NO 89
ISL 90
ISLAND 91
True North
45 feet of Low Water
60 feet of Low Water
19
20
1878 BEFORE IMPROVEMENT
STEAMBOAT CHANNEL 1878
1915 AFTER IMPROVEMENT

PLATE III

spurs to a 4-foot stage above low water and closing Dresbach Slough. It is seen that the contraction is small and the bar has not been cut down entirely, only a cut of relatively small width (250 feet) was made, but sufficiently large for navigation. The section flow has not been increased to any extent—it has merely gained in depth what it lost in breadth.

The survey of 1878 on Plates II, III and IV, with the given channel course, shows the many abrupt and sharp turns that were necessary in order to follow the course. It will be noted in the improved channel that these sharp curves and right-angle crossings have been eliminated and smooth, regular curves substituted, vary-

Partially Completed Spur Dam.

ing from 1 to 3 degrees, which shortened the sailing course 2½ miles. The curve on Plate I has a radius of approximately 3,000 feet, or is about a 2-degree curve. From a study of the various curves in the section, a 4,000-foot radius or even larger seems the logical one to obtain a uniform depth and width.

The bank between E and F, Plate I, would have crumbled away by the deflected current caused by the construction of spurs 58, 59, 60 and 61. To avoid this new mass of earth finding its way into the channel, shore protections are generally constructed before the building of the spurs, as the direction of the current is easily determined. The deflected current was evident at many sections throughout the reach and necessitated the construction of numerous shore protections.

Longitudinal dams, as No. 57, Plate I, perform about the same function as a riprapped bank. The water tried to force its way down Dresbach Slough, due to the deflected current caused by spurs 39 and 40. To overcome this course of the water, dam 57 was constructed with spur 72, which in turn held the course in its desired position. In some places spurs are necessary, but the bank is too low to permit their construction (see Islands 74, 76, 83, 98 and 102), and at these places longitudinal dams are built to form a shore end high enough for the necessary spurs to start from.

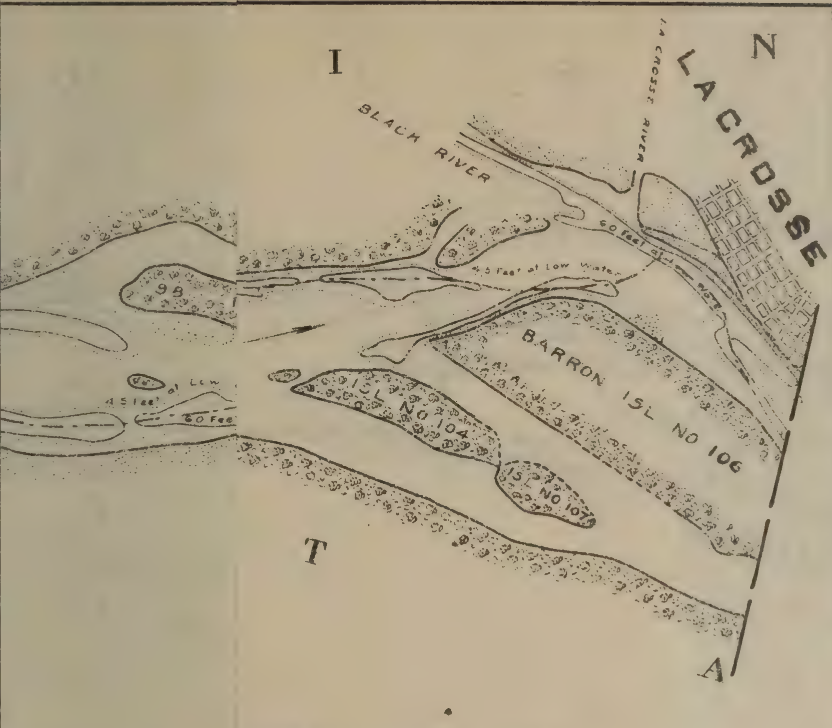
During high stages bars are formed in the channel, and during low water the river again reconstructs itself to its former course

Completed Spur Dam.

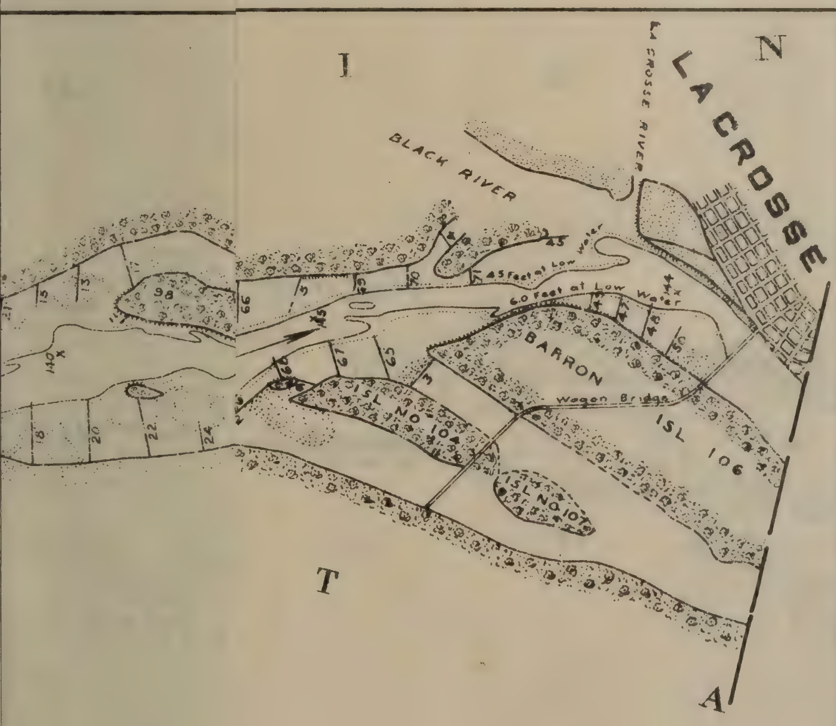
and depth. This return to its former channel and depth is partly controlled by the construction of closing dams, as No. 71, Plate I. From the 1878 survey, shown on Plate I, it is seen that considerable water was passing through the secondary arm (Dresbach Slough), while the 1915 section shows most all the low water flow has been concentrated into the channel desired. Dresbach Slough is partially filled up and in some places bars have formed with willow growths, making this arm nothing more than a shallow bayou.

The all-important question that arises is, Where is the material (sand) which was in the former obstructions? Has it moved downstream into another reach?

Most of the sand has been put permanently out of the way in

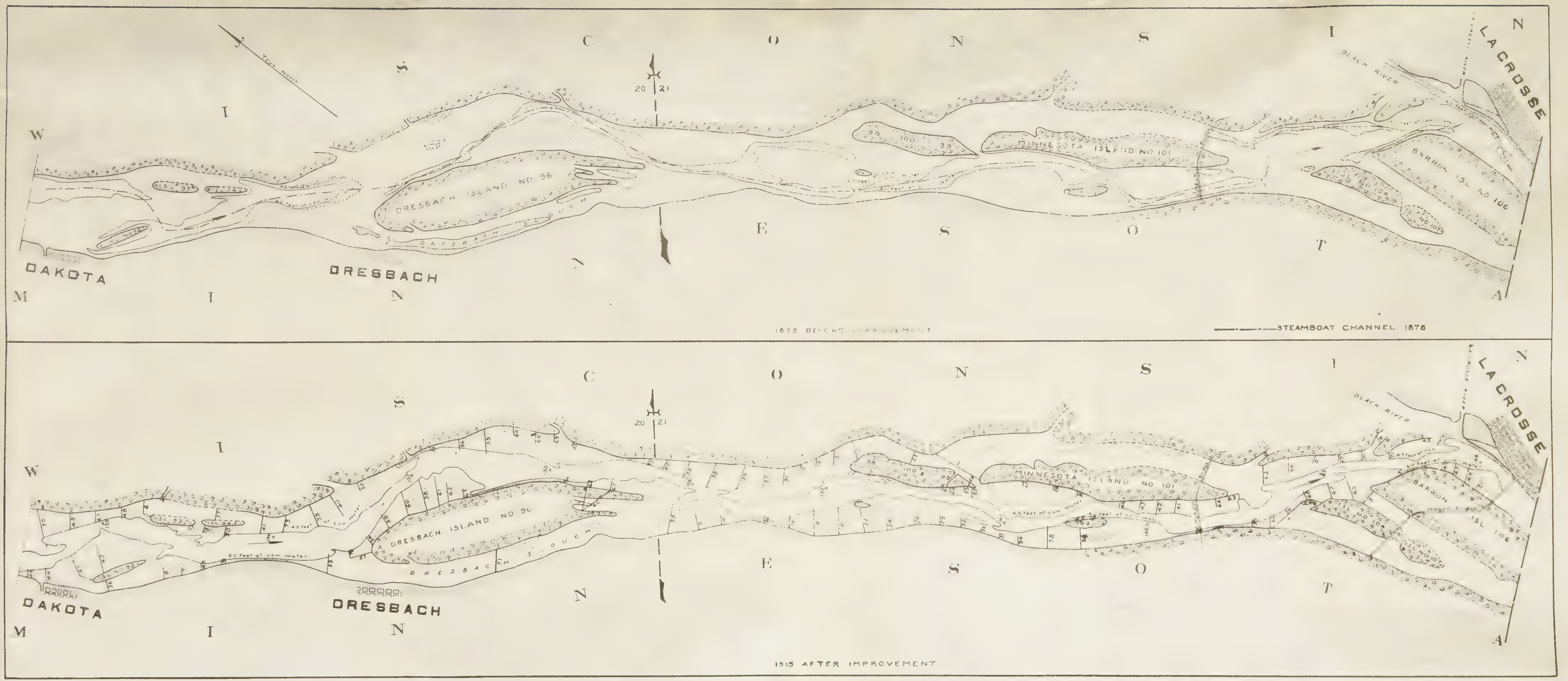


BEFORE IMPROVE TEAMBOAT CHANNEL 1878



AFTER IMPROVE

PLATE IV



W I S C O N S I N
M I N N E S O T A
LA CROSSE
BLACK RIVER
DAKOTA
DRESBACH
DRESBACH ISLAND NO 96
DRESBACH SLOUGH
MINNESOTA ISLAND NO 101
BARRON ISL NO 106
20 21
STEAMBOAT CHANNEL 1878
1915 AFTER IMPROVEMENT

PLATE IV

the following manner: By a lateral movement, sand banks have formed between the dams (see Plates II, III and IV) extending downstream from one dam to another, which has helped to bound the channel and give it the desired direction. It has also been permanently deposited in the closed-off secondary arms. The sand has not moved downstream, as the reach just below the one in question does not show this to be the case. Instead it has been partially improved and shows far better condition than in 1878.

The entire cost of the improvement of this section of river has been, for construction and dredging, \$1,475,887.97, or \$51,785.64 per mile. In this work there have been used 659,506.7 cubic yards

Completed Shore Protection.

rock and 1,451,312.3 cubic yards brush, or 2,110,819 cubic yards total material, at an average cost of \$0.695 per yard. There are 296 spur, longitudinal and closing dams, aggregating 179,076 feet in length, or about 34 miles, and 64,693 linear feet of shore protection, approximately 12 miles.

The approximate quantity of sand moved and permanently lodged in this section is about 13,761,965 cubic yards, at a cost by the construction methods noted of approximately $9\frac{1}{2}$ cents per yard.

In obtaining a continuous minimum depth of 6 feet at low water, there will naturally be, owing to the configuration of the river bottom, a very large proportion of much deeper water, from 6 to 12 feet or over, which is a very great advantage in accelerating

the speed of boats. If such channel is too narrow, it can be widened by submerged dams or dredging, which will seldom be resorted to.

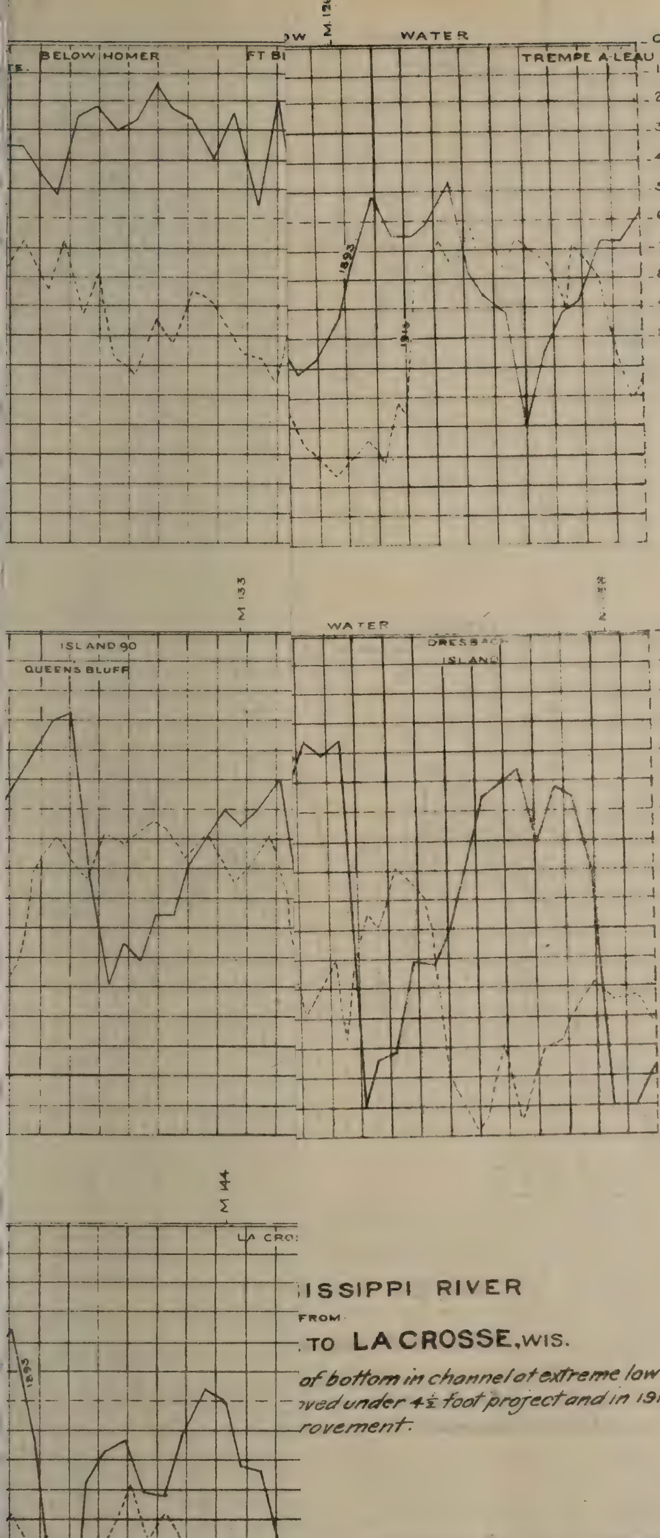
In this improvement, the water surface slope and velocity of current have not been materially or detrimentally changed, nor has the bed of the river risen. The 6-foot channel has been established by contraction of the main waterway to 625 feet in width up to a 4-foot stage, by means of spurs in the main river, closing dams in the side chutes, with systematic alternations of spurs from one bank and shore protections on the other, and in some cases spurs from both banks. The regulation works are substantial enough to withstand most river actions, which should make the maintenance cost very low.

COMMENTS *by* MAJ. G. M. HOFFMAN, *District Engineer Officer.*

Before improvement, this section of the Mississippi River was the most obstructed by moving sand bars of any reach except that between Lake Pepin and Winona. The original project, formulated in 1879, but without any definite estimate of cost, contemplated by means of waterway contraction a 4½-foot channel at low water, eventually to be increased to 6 feet. The proposed contracted waterway in this section was to be 800 feet in width, which was reduced to 625 feet in the current 6-foot project. Up to the time of the adoption of the 6-foot project in 1907 the work had not been continuous, but applied to the worst localities in turn, so that in 1907, or in fact until 1910 when larger appropriations became available, there was little continuity in the work as viewed from the standpoint of a through 6-foot channel, although even with this incomplete regulation much improvement was effected and the greater part of the entire length of 658 miles from St. Paul to the Missouri River was benefited to the extent of probably 18 inches of additional depth, and that portion of the river from St. Paul to Lake Pepin (56 miles) had at the time of the adoption of the new project been improved for fifteen years, so that this part, formerly the shoalest with high bars at nearly every crossing, had a channel of 4½ feet, which at present after twenty-four years and without any cost for maintenance does not show excessive deterioration.

While the section of river which is the the subject of this article is the longest continuous stretch of fully improved river (omitting the 45 miles of back-water improvement incident to the construction of the power dam at Keokuk), there are many others of good length, so that, taken together with the stretches of naturally good river, about 567 miles of the 658 now have equal or greater depths than that projected; it is a logical assumption that the remaining 91 miles will, with suitable allotments of funds, respond to the methods employed in the section under consideration.

A table follows which shows in feet the depth below low water,



ISSIPPI RIVER

FROM

TO LA CROSSE, WIS.

of bottom in channel at extreme low
ved under 4½ foot project and in 1915
rovement.

PLATE V

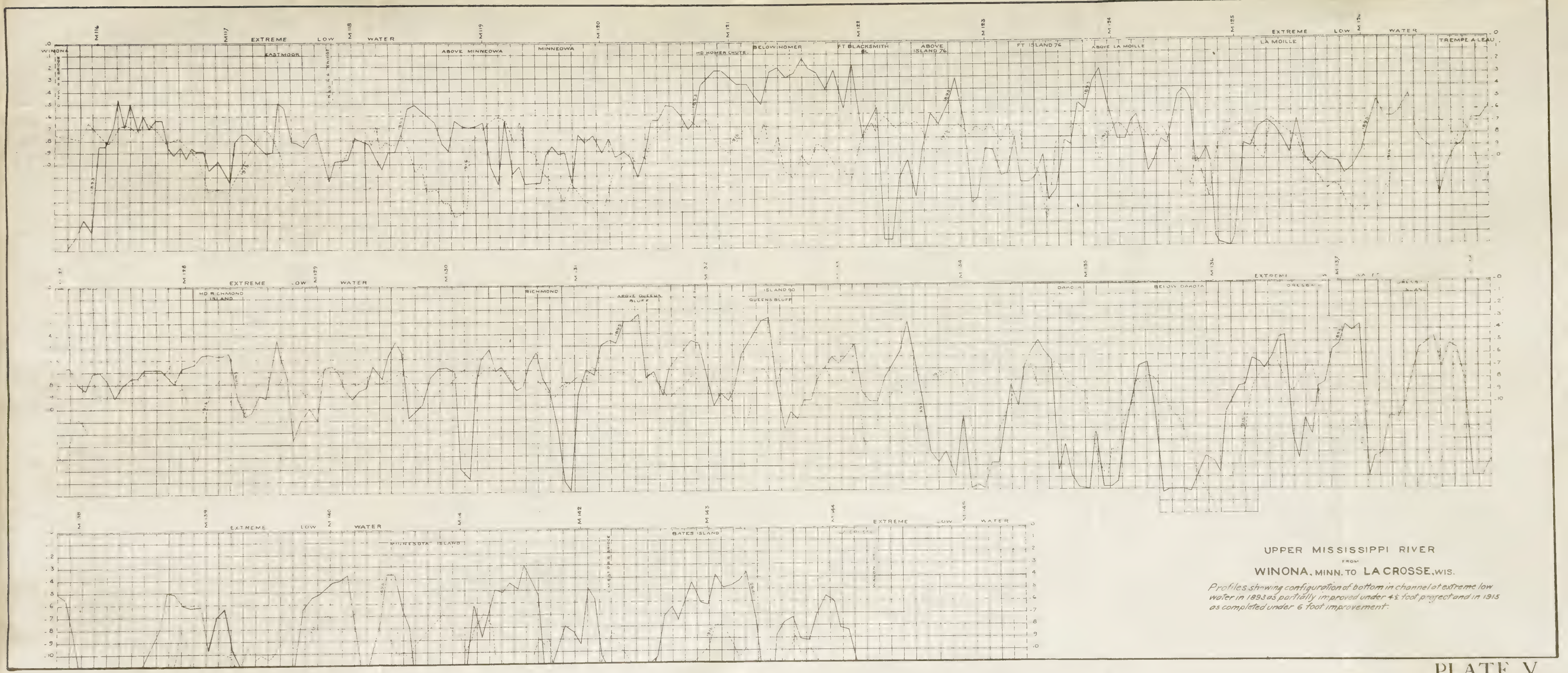

UPPER MISSISSIPPI RIVER
FROM
WINONA, MINN. TO LA CROSSE, WIS.
Profiles showing configuration of bottom in channel at extreme low water in 1893 as partially improved under 4½ foot project and in 1915 as completed under 6 foot improvement.
EXTREME LOW WATER
WINONA
EASTMOOR
ABOVE MINNEOWA
MINNEOWA
HD HOMER CHUTE
BELOW HOMER
FT BLACKSMITH
ABOVE ISLAND 76
FT ISLAND 76
ABOVE LA MOILLE
LA MOILLE
TREMPE A LEAU
HD RICHMOND ISLAND
RICHMOND
ABOVE QUEENS BLUFF
ISLAND 90
QUEENS BLUFF
BELOW DAKOTA
MINNESOTA ISLAND
BATES ISLAND
M 116
M 117
M 118
M 119
M 120
M 121
M 122
M 123
M 124
M 125
M 126
M 128
M 129
M 130
M 131
M 132
M 135
M 136
M 137
M 139
M 140
M 142
M 143
1893
1915

PLATE V

obtained by deducting the river stage from the soundings. Net depths so obtained are on the safe side, as the bars generally cut out with a fall in stage; as the same method is used for all the years mentioned, a good comparison is afforded and it may well be reasoned that the showing during the comparatively high stages of 1915, although nowhere less than 6 feet, would be even better had the river fallen to near low water. Where the letter G occurs a depth of 4½ feet or more is indicated, but as the crossing was known to be good, no soundings were made.

The progressive improvement is shown at most of the bars named.

Table of depths below low water for various years at the worst bars in the section.

Name of bar.	1893	1894	1910	1911	1912	1913	1914	1915
Below Winona (Eastmoor)	2.8	3.1	G	3.6	5.9	4.6	7.0	6.5
Head of Homer Chute	3.7	4.1	G	G	6.4	8.0+	7.5	6.3
In Homer Chute	1.1	2.5	G	G	7.0	8.0+	6.5	6.3
Mt. Trempealeau	1.5	2.3	G	G	6.0	6.0	6.5	6.3
Above La Moille	G	3.7	2.6	G	8.0+	6.0	8.0+	7.0
La Moille	---	2.5	G	G	6.4	8.0+	8.0+	7.3
Above Trempealeau	3.0	3.2	G	4.7	7.0	8.0+	7.5	6.4
Below Trempealeau	G	3.8	G	G	6.2	5.0	7.0	6.9
Above Richmond	2.5	3.8	3.5	G	5.3	6.7	5.3	6.3
Above Queens Bluff	G	G	G	4.2	3.5	7.0	7.0	7.0
Queens Bluff	1.6	3.0	G	G	4.5	6.6	7.0	6.9
Above Dakota	G	G	3.1	4.0	3.7	8.0+	8.0+	6.9
Opposite Dakota	G	3.3	G	G	4.2	6.5	5.0	6.2
Below Dakota	G	G	3.1	G	5.0	8.0+	7.0	7.3
Head of Dresbach Island	G	1.8	G	G	8.0+	8.0+	6.5	7.5
Opposite Dresbach Island	G	G	G	G	8.0+	8.0+	8.0+	8.0+
Foot of Dresbach Island	2.2	3.2	G	G	8.0+	8.0+	7.0	8.0+
Minnesota Island	G	G	3.2	G	8.0+	8.0+	7.5	7.0
Above La Crosse	2.0	2.4	4.2	3.4	3.6	4.0	7.6	8.0+
Opposite La Crosse	2.8	3.6	G	G	8.0+	8.0+	8.0+	8.0+

Profiles (Plate V) are herewith, showing improvement from 1893 to 1915, in which latter year the 6-foot channel depth was obtained.

It will be seen (Plates II to IV) that at several points, notably at Winona, Minneowa, below Homer, foot of Blacksmith Slough, Trempealeau, Island 91 and above, the improved channel, although a practicable one, is not as wide as is desirable. It is expected that it will widen in time, but if such action is prevented by hard bottom, a dredge will be used. Some future deterioration in the channel may occur at times from the formation of bars moving downstream in the channel, but experience indicates that such formations will be narrow and of no great quantity, so that they readily be removed by dredges.

Construction of North Guide Wall of Troy Lock

WITHOUT ENCLOSING WITH COFFERDAM.

BY

Mr. JOHN J. McCABE,
Junior Engineer.

The North Guide Wall extends 235 feet north from the upper end of the outside, or river wall of the lock, providing an arm along which tows are able to straighten out and make a clear entrance to the lock.

The considerable depth of water (20 to 25 feet) in which the wall had to be built and the small amount of concrete involved (about 2,800 cubic yards) would have made the cost of construction in a cofferdam extremely high, and the use of pre-cast cribs for the substructure was therefore recommended to the Chief of Engineers by Col. Wm. M. Black, the District Officer. These had the additional advantage of providing air-hardened surfaces which would would resist injury from frost and ice, and which would offset weaknesses from the occasional layers of washed aggregate which seem unavoidable with concrete laid in water. It may be added that the design, although somewhat restricted by having to use light units (the maximum weight of crib which could be handled by the plant was about 7 tons), worked out successfully and economically, the total field cost of the wall being less than $9.00 per cubic yard.

The wall (shown in plan and elevation, Fig. 1) is made up of stepped piers, 21 feet 9 inches long at the base, 10 feet wide and placed 20 feet center to center, with a top elevation of +13.0 (mean sea level) carrying a continuous superstructure 12 feet high with a section decreasing in width from 14 feet at pier tops to 7 feet at the coping.

The wall was constructed without using a cofferdam by building the piers with pre-cast, hollow, rectangular, reinforced concrete cribs, conforming to the section of the piers, set by a diver,

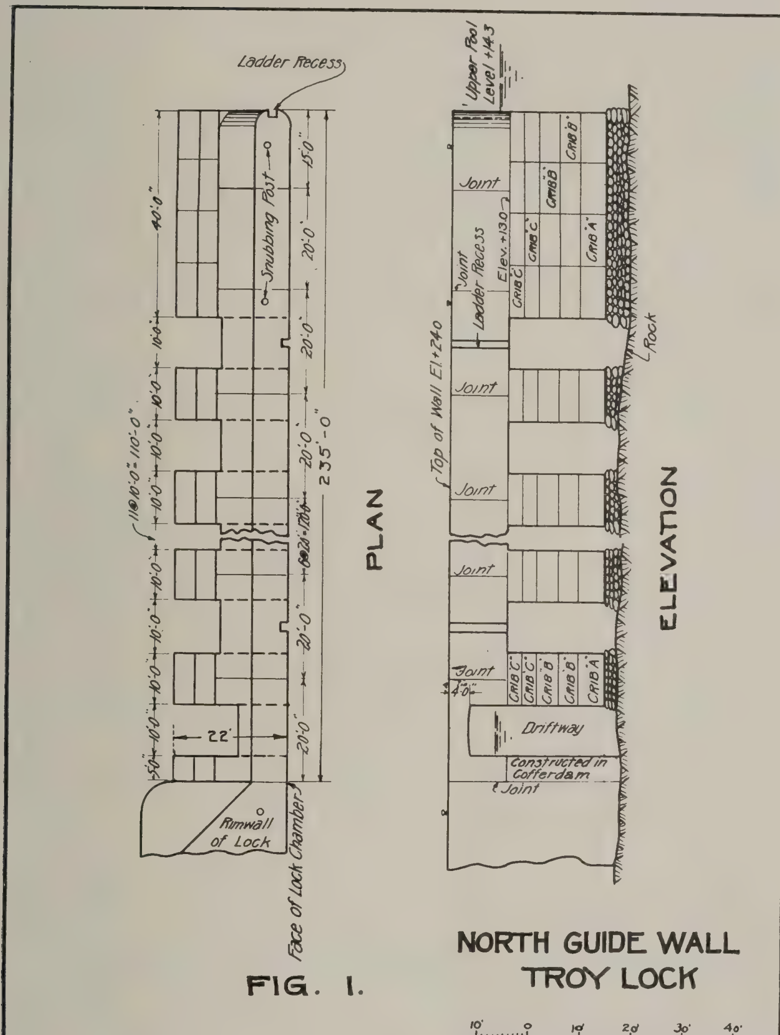


FIG. 1.

NORTH GUIDE WALL
TROY LOCK

and filled with concrete poured under water. The superstructure was to be built upon these filled cribs with the usual wall forms and the concrete placed by bucket. This would require the forms for the superstructure to be set in at least 2½ feet of water, and as there would be a possibility of getting washed concrete at the faces when pool level would be above normal during the pouring, and also as the placing below water of the floor forms bridging the opening between the piers would very likely be slow and troublesome, it was decided to bridge the opening between piers up to elevation +16.3, or 2 feet above normal pool level, with pre-cast reinforced concrete girders for the faces, and with slabs for the floors, these being keyed into the concrete poured above the slabs. The superstructure was then continued with the usual forms, lapping the girders and extending to top of wall. Fig. 2 shows a section of the wall as made up of the cribs, girders and slabs. the number marked on each giving the order in which it was placed. Fig. 3 shows the details of a typical crib. A total of 78 cribs was required.

The cribs were designed to have a width equal to that of the piers, and to be strong enough to resist the pressure of concrete poured into them after having been cast seven days, and yet light enough to be handled by the plant on the work. The latter point necessitated a small size of crib with very thin walls and with ample reinforcement, including diagonal and lateral cross rods running through each. These interior rods proved troublesome while filling the cribs with concrete, as they interfered with the placing of the tremie and very often fouled it when it was necessary to lower it quickly to prevent loss of the charge when the concrete would at times suddenly start moving from the mouth of the pipe.

The cribs, girders and slabs were built on the bank, about opposite the wall site, where a hydraulic dredge had discharged river sand and gravel while deepening the lock approaches. An analysis of this material showed it to be remarkably clean after having been discharged by the dredge (with about 3 per cent of silt and loam) and the sand and gravel suitably proportioned for concrete. Accordingly, this material was used for concrete without first separating, enough cement being added to give a mix of 1 : 2 : 4 proportion.

FIG. 2

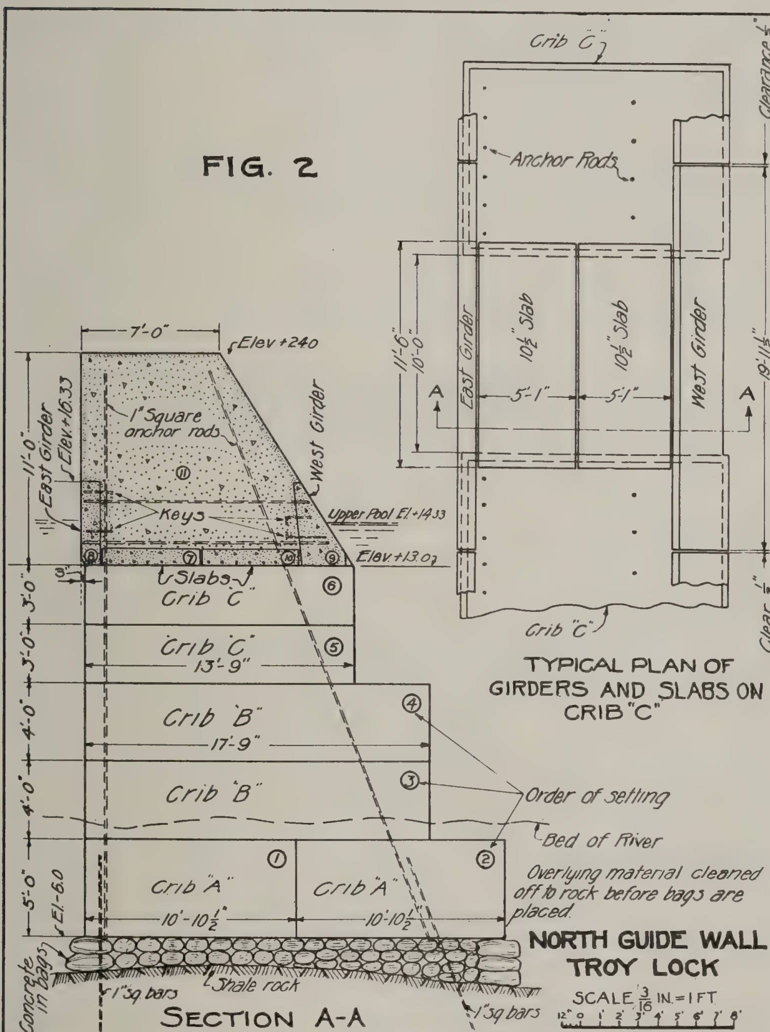
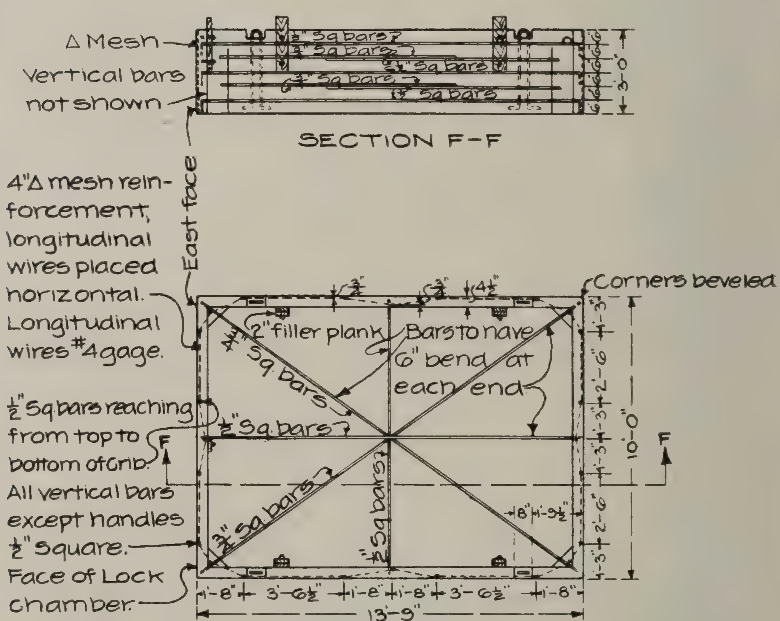

Crib "C"
Anchor Rods
East Girder
$10\frac{1}{2}$" Slab
$10\frac{1}{2}$" Slab
West Girder
5'-1"
5'-1"
11'-6"
10'-0"
19'-$1\frac{1}{2}$"
Clearance $\frac{1}{2}$"
Clear. $\frac{1}{2}$"
A
A
Crib "C"
TYPICAL PLAN OF GIRDERS AND SLABS ON CRIB "C"
7'-0"
Elev +24.0
1" Square anchor rods
East Girder
Elev. +16.33
West Girder
Keys
Upper Pool El. +14.33
Elev. +13.0
Slabs
Crib "C"
Crib "C"
13'-9"
Crib "B"
17'-9"
Crib "B"
Order of setting
Bed of River
Crib "A"
Crib "A"
10'-$10\frac{1}{2}$"
10'-$10\frac{1}{2}$"
Overlying material cleaned off to rock before bags are placed
El. -6.0
11'-0"
3'-0"
3'-0"
4'-0"
4'-0"
5'-0"
Concrete in bags
1" sq. bars
Shale rock
1" sq. bars
SECTION A-A
NORTH GUIDE WALL
TROY LOCK
SCALE $\frac{3}{16}$ IN. = 1 FT.

Table of Cribs.

Crib.	Length.	Width.	Depth.	No. required
Crib A	10′ 10½″	10′ 0″	5′ 0″	25
Crib B	17′ 9″	10′ 0″	4′ 0″	24
Crib C	13′ 9″	10′ 0″	3′ 0″	24
Special Crib A (same dim. as Crib A with 1 cor. beveled 3′ 6″)				1
Special Crib B (same dim. as Crib B with 1 cor. beveled 3′ 6″)				2
Special Crib C (same dim. as Crib C with 1 cor. beveled 3′ 6″)				2
Total				78

Note.—Use 1: 2: 4 concrete with aggregate not larger than 1 inch.



Top View.

Fig. 3. Reinforced Concrete Cribs, North Guide Wall, Troy Lock. Detail of Crib "C."

Cost of Making Cribs, Girders and Slabs.

Labor—		
Form work (includes placing reinforcement)	$2,550.59	
Mixing and placing concrete (by hand)	1,190.38	
Handling cement	105.48	
Construction of plant and miscellaneous charges	330.12	
Total		$4,176.57
Material—		
Cement (at $0.85 net)	$413.10	
Reinforcement	583.89	
Material and supplies incidental to construction	314.05	
Miscellaneous	129.85	
Total		1,440.89
Total, labor and material		$5,617.46
Total number of cubic yards		324
Cost per cubic yard		$17.34
Cost per linear foot of wall		23.95

The concrete was mixed and placed by hand. The form work on the cribs progressed slowly, as the very narrow walls made properly enclosing the mesh and reinforcement difficult.

While casting the cribs, girders and slabs, a hydraulic dredge cleaned off the site of the wall and it was intended to start placing the cribs as soon as enough of them had aged seven days. However, the urgent need elsewhere on the work of the derrick boat assigned to set the cribs, delayed the placing of the pre-cast parts until they had nearly all been completed.

Soundings taken after the dredge had been over the site of the wall showed the rock to be very irregular, with high spots not encountered in the early soundings and which were above the elevation determined upon as the base of the cribs, this elevation being such as to give a minimum volume of concrete to be placed in bags by the diver as a base for the cribs. A drill boat drilled and blasted these high rock spots, and the irregular pockets of material overlying the rock and not reached by the dredge were cleaned up by using the charging derrick and clam shell of the concrete boat, casting the material outside the limits of the wall.

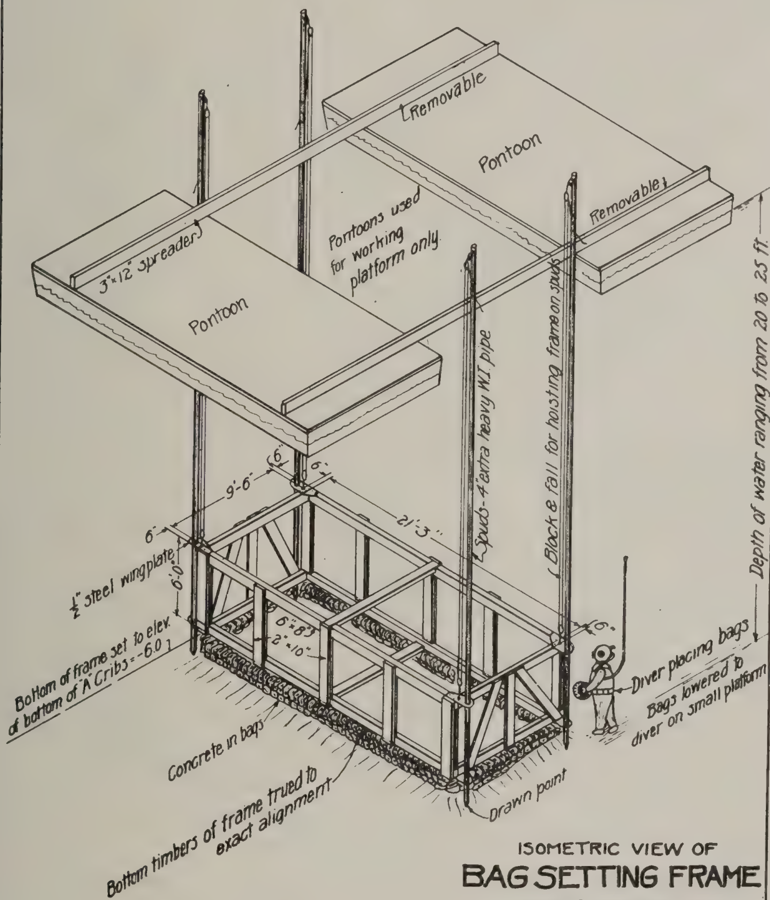
Cost of Blasting High Rock and Cleaning Off Rock Surfaces.

Labor—		
Drilling and blasting	$43.65	
Cleanup with clam shell	459.53	
		$503.18
Material—		
Dynamite and miscellaneous	$42.71	
Coal	119.55	
		162.26
Total, labor and material		$665.44

(Yardage not known, as material was cast outside of wall limits as excavated.)

After the rock had been prepared, the surface was leveled with concrete in bags placed by a diver on the lines of the crib walls and brought to the elevation of the bottom of the first tier of cribs.

Burlap bags were filled with concrete on the deck of a mixing boat placed alongside and moved along the site as the work progressed. This concrete boat was provided with a complete 1-yard mixing outfit, with a derrick on one end for filling the sand and gravel bins and another on the opposite end for placing the concrete. As the bags were filled they were placed on a platform swung from the placing derrick and lowered to the diver. To guide the diver for both line and elevation when placing the bags, a setting device was used (Fig. 4) consisting of two rectangular frames set 5 feet apart, braced together and hung on spuds of 4-inch extra heavy iron pipe by block and tackle operated from above the water. This frame conformed to the outline of the base of the piers and was set by lining the spuds from shore and lowering the frame on the spuds to the required elevation. After the frame was leveled, by reading on the four corners with a rod reaching above the water, the diver placed the bags of concrete, one bag wide, crosswise of the bottom timbers until the space between the bottom of the frame and the rock was filled. When the frame was removed four walls with level tops were ready to receive the first crib.



ISOMETRIC VIEW OF
BAG SETTING FRAME
NORTH GUIDE WALL
TROY LOCK

FIG. 4.

Cost of Placing Concrete Under Water in Bags.

Labor—		
Mixing and placing concrete in bags	$2,443.39	
Handling cement	43.25	
Digging sand and gravel	28.62	
Miscellaneous	391.67	
		$2,906.93
Material—		
Cement (at $0.85 net)	$121.55	
Burlap bags	260.68	
Coal	101.54	
Material and supplies incidental to construction	37.37	
		521.14
Total, labor and material		$3,428.07
Total cubic yards of concrete placed		143
Cost per cubic yard		$23.97
Number of bags placed		5,793
Cost of mixing concrete, filling one bag and placing		$0.59

To guide the diver in setting the cribs, a frame, as shown in Fig. 5 was used. This frame, provided with short spuds of solid 2-inch steel, was lined and plumbed from above water. The faces of the frame timbers were carefully dressed to a plane surface, well braced together to prevent warping and kept always in water to prevent drawing by the sun.

When the bottom cribs had been set on the prepared foundations, a drill boat drilled the holes for the anchor rods. The diver spotted the drill by using the walls of the cribs for a guide, telephoning instructions for shifting the drill boat as desired. Care was taken in shifting and placing the drill not to foul the interior rods of the cribs, and thus displace the cribs. As each hole was drilled and cleaned the anchor rod was dropped in and grouted from the deck of the drill boat, using a casing reaching well above water.

After the anchors had been placed the upper cribs were set and the long vertical reinforcing rods worked down between the cross rods of the cribs, clipped to the anchors and held in place at the surface of the water with a wooden template guyed to the handles of the top crib.

It being near the close of the season for river work when the bottom cribs were set, it was realized the wall could not be completed to top of cribs, so the bottom cribs only were placed and filled the first season, excepting those of the continuous 40-foot

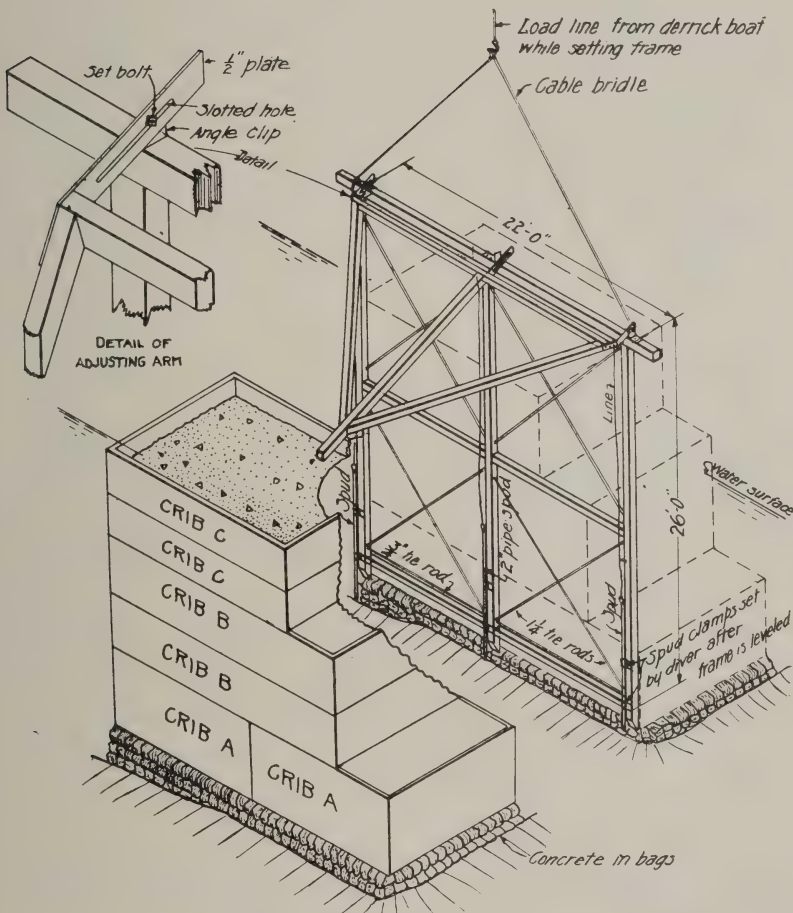


Fig. 5. Isometric View of Crib Setting Frame, North Guide Wall, Troy Lock. All timbers of frame are trued to exact alignment.

section at the north end which were placed to the top and filled.

This necessitated the diver clipping short rods to the anchors in all cribs but those of the north end to provide for lap of the long rods to be placed the following season. This nearly doubled the cost of placing the reinforcement.

Cost of Placing Anchor Rods and Reinforcement.

Labor—		
Drilling	$203.59	
Placing anchors and reinforcement, and grouting	1,051.82	
Miscellaneous	55.86	
		$1,311.27
Material—		
Cement	$30.00	
Rods	234.50	
Coal	20.00	
		284.50
Total, labor and material		$1,595.77
Total number of pounds of rods		21,154
Cost per pound		$0.075
130 5-foot holes drilled	feet	650
Cost per foot drilling		$0.313

When the reinforcing rods were in position the cribs were filled with concrete poured through a tremie.

When first used the tremie was hung between two pontons from a heavy frame carrying the hopper into which the concrete was discharged, and operated by block and tackle leading to a hand winch on the pontons. Three different lengths of pipe were used, the longest about 22 feet, shorter sections replacing the longer as the concrete was brought up. This rig was cumbersome, slow and difficult of operation and very often allowed the charge of concrete in the pipe to get away before the pipe could be lowered quickly enough to check the flow. Washed concrete resulted in spots and had to be removed later by the diver.

Nearly half of the concrete in the cribs was poured with this rig, but as soon as a derrick boat was available only the longest length of pipe was used by hanging it directly from the hopper, which was surrounded by a working platform, the whole swung from the derrick boom. The pipe, filled with concrete, was easily and quickly raised or lowered by the derrick with no time lost for

changing pipe lengths, and resulted in saving fully 50 per cent of time as well as giving more satisfactory concrete.

Cost of Placing Concrete under Water with Tremie.

Labor—		
Mixing and placing concrete	$2,538.34	
Handling cement	353.63	
Digging sand and gravel	391.30	
Miscellaneous	230.27	
		$3,513.54
Material—		
Cement (at $0.85 and $1.25 net)	$1,576.40	
Coal	86.42	
Supplies and material incidental to construction	61.93	
		1,724.75
Total, labor and material		$5,238.29
Total cubic yards placed		1,448
Cost per cubic yard		$3.62

The concrete for filling the cribs was a 1 : 3 : 6 mix with enough water to make a mushy mass, but not wet enough to cause water to collect at the top while standing in the hopper. To prevent the initial charge from dropping through the water, a gunny sack was stuffed with straw and rammed into the top of the pipe. The concrete was then lowered on to it, forcing it down slowly When the sack reached the bottom it freed itself automatically and floated to the surface. This method proved quite satisfactory.

The first concrete poured through the pipe was made about as stiff as that placed in open forms, but it would not only fail to flow away from the pipe into the surrounding area of the cribs but on two occasions arched and stuck in the upper part of the pipe, while the lower mass dropped to the bottom with the resulting vacuum which collapsed the pipe as flat as if it had been through a train of rolls. The matter of the consistency of the mix greatly affected the speed of placing the concrete, the fairly soft mix being easier to get through the pipe quickly and continuously, moving more evenly away from the end of the pipe and not washing like the drier mix, as it seemed to stick in a mass better under water and resisted percolation by the agitated water beyond the outer film of mortar. Because of the mass of cross rods in the crib the

pipe had to be set each time by the diver, as it was impossible to work it down through the interior rods from above without great loss of time. This required the services of the diver at times during the pouring of concrete, as the limited volume allowed for continuous pouring necessitated frequent shifting of the tremie from one pier to another.

When the cribs were filled. a derrick boat set the girders and slabs. The 3-inch overhang of the superstructure may be noted, shown in Fig. 2. This was adopted so that if there were slight

Upper Guide Wall, Troy Lock, August 13, 1916.

irregularities in setting the cribs (as was unavoidable) there would be no part projecting beyond the face of the superstructure. The girders were lined by a transit from the lock wall and held in position by two rows of short rods placed in holes provided in the girders and joined by long rods between with a sleeve joint just inside the girders, allowing the short rods through the girders to be removed after the concrete had set. On top of these rods were placed 4 by 4 inch struts cut to correct distance between inside of girders, and removed as the concrete was brought up to them.

Cost of Transferring and Setting Cribs, Girders, and Slabs.

Labor—		
Diving and derrick boat crews and laborers	$3,547.65	
Construction of plant, repairs and miscellaneous	611.09	
		$4,158.74
Material—		
Coal	$253.77	
Supplies and material incidental to construction	85.54	
		339.31
Total, labor and material		$4,498.05
Total linear feet of wall		235
Cost of setting, per linear foot		$19.14

Concrete was next poured between the girders to their tops and the forms for the remainder of the superstructure set on timbers bolted to the girders a little below the top, using the short rods through the girders mentioned above. No difficulty was met with in placing the upper forms, except that work on the outside of the forms had to be done from floats.

Cost of Superstructure.

Labor—		
Form work	$1,315.04	
Setting iron and steel	94.87	
Mixing and placing concrete	439.18	
Handling cement	182.85	
Digging sand and gravel	65.48	
Miscellaneous	296.41	
		$2,393.83
Material—		
Cement	$1,141.25	
Cast iron and steel	378.30	
Coal	103.86	
Supplies and material incidental to construction	92.18	
		1,715.59
Total, labor and material		$4,109.42
Total cubic yards placed		913
Cost per cubic yard		$4.50

The work was carried on during the navigation period with boats constantly entering and leaving the lock and was repeatedly interrupted by tows hitting the setting frames, on two occasions damaging them so that they had to be sent to the bank for repairs. After the north end section had been brought to the water surface, the work was guarded by a cable stretched from the cribs at that

end to the river wall, on the lock side, with heavy timbers stapled to it and floating on the surface of the water. These fenders could not be placed much beyond the face of the wall because of obstructing the lock approach and there was enough spring in the cable to allow a boat bumping the timbers to hit the uncompleted work. Several of the top cribs had to be reset and there was continual trouble with the girders being struck before the concrete had been poured their height.

The diving crew consisted of two divers, each doing a four-hour trick below the water while the other directed operations above, with two men on the pump, one man tending the telephone connected with the diver's helmet and one man tending the life and telephone lines and air hose. This crew was provided with a small scow about 11 by 25 feet, with a shelter on deck for storing the pump and equipment and for drying out the diving dresses when not in use. A ladder, swung from the side of the scow, allowed the diver to descend below the water surface before swinging from the life line to be led by the attendant to the desired spot. The divers were employes of the Engineer Department already connected with the work at Troy as foremen, experienced in diving work, and who proved exceptionally reliable and efficient. The derrick boat crew for handling the cribs, girders and slabs consisted of the engineman, fireman, and four laborers who handled the tag line from the cribs, etc., when being set, swinging the pieces as directed by the diver through the telephone. These two crews with the watchmen, were employed continuously on the guide wall work. When concrete was being placed, another derrick boat, with an engineman and fireman for handling the tremie when in use, and the concrete crew, consisting of foreman and nine men, were used in addition.

Summary of Costs.

Item.	Labor.	Material.
Making cribs, girders and slabs	$4,176.57	$1,440.89
Placing concrete under water in bags	2,906.93	521.14
Transferring and setting cribs, girders and slabs	4,158.74	339.31
Placing concrete under water with tremie	3,513.54	1,724.75
Anchor rods and reinforcement	1,311.27	284.50
Superstructure	2,393.83	1,715.59
Blasting high rock spots and cleaning off rock	503.18	162.26
	$18,964.06	$6,188.44

Grand total	$25,152.50
Total cubic yards	2,828
Total linear feet of wall	235
Cost per cubic yard of concrete	$8.89
Cost per linear foot of wall	$107.04

Costs do not include overhead of district and field offices, or depreciation of plant. The cost of excavation by hydraulic dredge could not be gotten, as the charges were not separated from lock excavation.

John D. Kurtz.

BY

Lieut. CHARLES P. GROSS,
Corps of Engineers.

Brevet Colonel John D. Kurtz was born in Washington, D. C., in October, 1819. He entered the Military Academy in 1838 and was graduated in 1842, when he was commissioned as a Second Lieutenant in the Corps of Engineers. Until his death, in 1877, he served continuously in the Corps, rising to the rank of Lieutenant Colonel.

Although his years of service spanned two great wars, he took little part in the active operations of either, and thus the story of his life has little of the picturesque familiar to the lives of many of his contemporaries. But his was a life of service well and efficiently done. While the popular ear was unfamiliar with his name, those officers and men with whom he came in contact recognized the able officer. He was a gentleman of intelligence and education, of a large experience in men and affairs, of sound judgment, so impartial in his decisions and so noble in character as to command the respect and admiration of his fellows, and withal so modest in disposition, so kind and courteous in his social intercourse as to gain and to hold the love and affection of all.

His professional services were various and important. Upon graduation, he was sent to Charleston, S. C. For nine years, until 1851, he served as assistant engineer and later as engineer in charge of the construction of permanent fortifications in Charleston Harbor, and of the repairs and preservation of the sites of Forts Macon and Caswell, N. C. So constant was his attention to his duties and so protracted his exposure to the rigor of that climate that he left that station broken down in health. In the hope that he might recuperate, he was transferred to the Office of the Chief of Engineers, where he remained until 1856. However conducive to health the nature of his duties may have been, he never regained its full vigor. From 1856 to 1860 he superintended the forti-

fication work at Portsmouth, N. H.; Fort Knox, Penobscot River; Fort Gorges, Portland; and Fort Popham, Kennebec River, Maine; and was engaged upon duties under the Light-House Department on Lake Champlain and upon civil works in Maine.

With the outbreak of the Civil War he was detailed as Chief Engineer of the Department of Annapolis. Later, he was transferred to the Department of the Shenandoah. Here, again, his health was not equal to the task of partaking actively in the campaign. Therefore, he was again detailed for duty in the Office of the Chief of Engineers, where his large experience and sound judgment proved to be valuable. During the time that Early threatened to raid the capital, he was active in strengthening the defenses of Washington. For his meritorious services in the Civil War he was brevetted Colonel in March of 1865.

Shortly after the war he was detailed to take charge of the fortification work of Baltimore and Washington, and later of the construction of the fortifications of Philadelphia. Civil improvements on the Delaware River and Bay and certain improvements on the Schuylkill and several rivers in New Jersey were also assigned to him. These duties occupied his attention until 1875. During the last year of his life he was in charge of laying the foundation for the Washington Monument. While so engaged death overtook him. He died at Georgetown, D. C., on October 16, 1877, at the age of 58.

Road Work in Mexico with the Punitive Expedition.

BY

Capt. JAMES A. O'CONNOR,

Corps of Engineers.

The Punitive Expedition into Mexico resulting from Villa's raid on Columbus, New Mexico, on March 9, 1916, furnished tests in men and material that it would have been impracticable to make in this country in recent years, except in case of an emergency. The lessons to be learned from these tests are of considerable value. They do not, it is true, cover the actual fighting of a force, but they show the possibilities of men and animals, give a measure of what they can do when properly trained and prepared, and indicate the suitability of the equipment that has been chosen for field service with the recent changes and developments.

The set of conditions, one of which is dealt with in this article, that caused the most concern were those connected with the question of transportation. The force sent into Mexico after Villa consisted of 5 cavalry regiments, 4 infantry regiments, 1 artillery regiment, 3 companies of engineers, with the necessary signal corps, and medical and quartermaster personnel. The greatest distance south reached was Parral, about 500 miles south by road from Columbus. The expedition headquarters were first established at Namiquipa, 243 miles south of Columbus, in the latter part of March, and remained there until the latter part of June, when they were moved to Colonia Dublan, 108 miles south of Columbus.

The transportation problem is divisible into two general periods: the first up to the Parral affair, when the object of the expedition was the capture of Villa and any other consideration was of secondary importance; and the second when the expedition was simply an army of occupation. In the first period supplies were urgently required and, as far as possible, were furnished. The truck trains that were purchased to supply the expedition were run day and night over dirt roads which for the first few trips did very well, but which rapidly became impassable. They were kept

moving as long as they could be made to run; what was demanded was to get there and no excuses were permissible. On such trucks as had them, the governors of the engines were removed and the running speed was the maximum that could be made. No advance base of supplies could be established, because the demand exceeded the supply. By the time the troops had ceased to advance and had been withdrawn to the north, in the latter part of April, the supply question was put on a firmer basis, largely as a result of the use made of the railroad between El Paso and Colonia Dublan. The supplies required by the expedition amounted to about

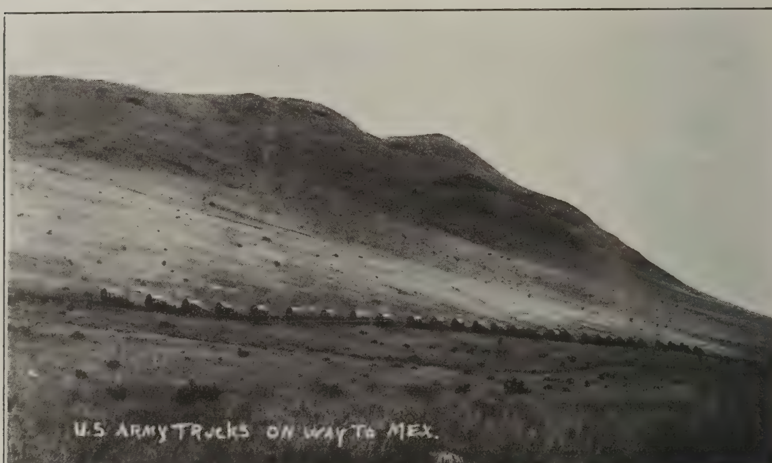
The dirt roads were good for the first few days.

200 tons daily; and as much of this amount as possible was sent by the railroad. The mail, ordnance, casuals, and supplies for the intermediate detachments and such other shipments as could not be sent down by rail were carried by truck trains, which transported an average of 40 tons daily.

With the furnishing of the most essential supplies, what might be called the second period in the transportation problem was reached. In this period the advance bases were established, first at Namiquipa, and after the further withdrawal in the latter part of June, at Colonia Dublan. The supplies were carried from the bases at El Paso and Columbus by railroad and by truck train

to the advance bases, and from there forwarded to the troops.

The maintaining of the expedition in Mexico depended largely on the regular furnishing of supplies. What little could be obtained from the country had been used up in the first movement. The section of Mexico that was occupied is not fertile, and the disturbances in recent years have resulted in nothing more being raised than that which the few inhabitants of the district required for existence. It was of considerable importance to establish at all stations a reserve for any ordinary emergency, such as would result from an attack or from an interruption of communications by any other means. To carry the 40 tons daily which was transported by trucks required an average of 1 train of 33 trucks.



While an average of 66 trucks per day passing over the road does not appear to be a large number, the destructive effects of this number of trucks run in trains are very great. In the first place, expert drivers were hard to obtain—for only those who cared to rough it would stay. The drivers were on the road up to twelve days at a time, sleeping out at night and in the daytime running in dust so thick that soon after they started on a trip no one could recognize them by their features or color. In addition, they were working early and late in getting out trucks that were stuck and in repairing others, so that they could keep running. This was work for youths and adventurous spirits, who were in the large majority, and the very qualities that fitted them for the work added to the truck and road problems.

In view of the necessity of accumulating reserve supplies, the speed of the trains was about the maximum they could maintain. The head of the column rarely averaged more than 15 miles per hour, but the opening out and closing up of the trucks resulted, to all intents and purposes, in running the trucks as fast as the material would stand and the road permitted, so that the better the road the higher the speed, and the limit of destruction to the road was that which the trucks could stand.

The problem presented the 2d Battalion of Engineers was to provide a road for this traffic. The section of Mexico that was

View of road in early days of expedition.

occupied is of the same general character as southern New Mexico. It is practically a desert plateau 4,000 feet above sea level at Columbus, about 5,000 feet at Dublan, and about 6,000 feet at Namiquipa, with a number of outcroppings and small ranges up to 3,000 feet above ground level. The valleys are plains of alkali, sand, gravel, clay, adobe, or caliche (a sand and gravel mixture), with their various mixtures. These soils vary from a fine, friable, alkali dust to a fairly compact sand, gravel, and adobe mixture. In sections where the road could be located on ground of this latter character, the results were satisfactory—these sections, however, were very limited. Using the caliche as a top dressing, good roads can be made during the wet season, but in the dry season the

caliche is readily ground up and soon destroyed by traffic. The general impression in passing over the country is that of alternating stretches of alkali and adobe plains. At the higher points, rocky ground is occasionally encountered. One of these sections is called "Jumping Jack Hills" by the truck drivers, because the passage of the trucks soon ground the soil around the rocks into a fine powder which had blown away, leaving a road which resembled a rocky creek bed. Although the winters are comparatively mild, there are frosts from October to March and temperatures as low as 0° F. The summers are very hot, but the air is dry and the nights cool.

The rain question was the interesting one. Without water, the roads soon became impassable and with too much of it it was almost universally feared that the traffic would cease. The evidences of heavy torrential rains are everywhere apparent. A day's rain in May had stopped all trains, and the natives and American scouts were positive in their statements that there could be no traffic in the rainy season. The rainfall records at Columbus, N. M., were used as a guide as to what could be expected. These showed the yearly rainfall to average about 10 inches, most of which fell during the principal rainy season in July, August, and September. Underground water can be reached in many sections, but it is hard to obtain. Between Columbus and Colonia Dublan springs and existing wells were available at only six places, which were from 7 to 37 miles apart. One well, driven in the center of one of the long sections, struck a limited supply of water at 623 feet depth.

In general, the problem consisted in providing roads for a traffic the main portion of which required a boulevard, under conditions where even good dirt roads were difficult to obtain. By the first part of April, all practicable road routes from Columbus to Colonia Dublan had been reconnoitered and by the 1st of May all practicable routes to San Antonio, 79 miles southeast of Namiquipa, had been examined. The troops had entered Mexico by way of the Columbus-Palomas-Boca Grande road, and thence via Espia and Ascension. The route adopted as a result of the examination was Columbus-Palomas-Vado de Fusiles-Ojo Federico-Corralitos Station-Dublan-Charcos-San Joaquin-El Valle-Las Cruces-Namiquipa-San Geronimo-San Antonio, until El Valle became the most southern point in the latter part of June.

Up to the 1st of June the work done was pioneering—that is, the roads were kept passable by filling chuck holes, removing rocks,

fixing arroyo crossings, and opening up new stretches as the roads became impassable and surfacing short, sandy sections. This pioneer work presented a number of problems. The chuck holes, for instance, were first cleaned out and filled with gravel, but the gravel was soon squashed out, or pushed out if was in loose, and, if it was made solid, chuck holes were readily formed on each end, making a worse obstruction than before. Satisfactory results were obtained in places by making the sides of the chuck holes vertical and filling with compacted broken rock or stone, but this material was rarely available. The rocky sections were simple

Palomas, Mexico.

problems for a suitable base and good material was available. Attempts were made to surface the sandy stretches with caliche and adobe mixtures and with gravel but without water, which was not available; this proved of little value. An experiment was made in building a plank track of 2 by 12 inch planks over a particularly bad, sandy stretch, but these were soon broken up. Where the roads crossed adobe or gravel, they lasted very well for several weeks, and when the ruts became too deep a new road was opened alongside the old one. Filling the holes without an available supply of water was found to be useless, as the disturbed ground was

readily ground into dust, which obscured such holes as might otherwise have been seen through the dust caused by the passing trains. Patching any road required careful work and selected materials, neither of which could be obtained.

In general, except for the very few favorable stretches above referred to, little could be done to repair the dirt roads, which, by June, had a covering from 1 to 2 feet deep of dust, of about the consistency of flour. The main solution was to open up new roads as soon as the old ones became worn and to keep the arroyo crossings in repair. The arroyos were dry, but crossing places were

Small arroyo crossing.

generally scarce. Where practicable and where timber could be obtained or furnished, bridges were built; in other places the crossings were paved. Before the beginning of the semi-permanent road, these crossings were made by cutting the banks to a convenient slope and building two tracks, 2 feet wide, of flat, two-man stones set on edge with their long dimensions crosswise, and tightly wedged. This pavement was sometimes covered with adobe or gravel. Considerable care was required in making these pavements, for with any looseness the stones were gradually pushed out of the way by the trucks and the effects of the pavement destroyed.

Two trestle bridges were built: one 180 feet long over the Casas Grandes River at Vado de Fusiles; and the other, 150 feet long, with a 1,050-foot stone causeway, over the Santa Maria River at El Valle. The Casas Grandes River was dry until the rainy season, when at times it had over 10 feet of water. The Santa Maria River was a flowing stream during the expedition and previous to the construction of the bridge it was fordable, but a small

Building a causeway for El Valle bridge.

rain made the ford impassable. The crossing at the bridge site was 1,200 feet wide, and the general design of the bridge was determined by the amount of lumber that could be obtained. This was one carload, which had been hauled 65 miles by native wagons and which permitted the construction of 150 feet of bridge over the main channel. The remainder of the crossing was a rock causeway with one 12-foot culvert. The undue contraction of the channel was considered at the time, but the bridge was expected

to last until the height of the rainy season, when conditions, as had been foreseen, were not pressing. It being impracticable to drive piles into the hard-pan of the river bed, small cofferdams, made of the bridge decking and adobe, were built. The trestle piles were sunk into the hard-pan and as large rocks as could be handled were piled around the bases of the trestles. The bridge was the ordinary type, with trestles 10 feet on centers with a rock-filled crib at the causeway end, and was erected by 30 soldiers in 26 hours. The causeway was built in 2½ weeks by 500 natives and 150 native wagons (5 and 6 mule). This bridge was washed out in August and again in September. The last time the span was increased 50 feet, which has so far proven sufficient to pass the high water.

It became evident by the 1st of June that the expedition would be in Mexico during the rainy season, and steps were immediately taken to provide for it. A proposition to build a plank road across the desert to Guzman and to use the railroad from there on was considered, as was also the construction of a plank road over the worst places in the existing dirt road from Columbus to Colonia Dublan. The plan to build a graded road as a wet-weather road and to continue the use of the pioneered roads in the dry season was finally adopted. The preparations for the new road included the purchase of machinery and the providing of about 60 Jeffery trucks. The road machinery purchased may be divided into five classes: tractors, graders, rollers, scrapers, and drags. Eleven tractors were purchased: 6 75-horsepower Holt caterpillars, where little weight is carried by the front wheel; 2 centipede tractors of the same general principle as the caterpillar, but where a considerable portion of the weight is carried by the front wheels; and 3 rear-wheel-drive tractors. Two rear-wheel-drive tractors were later hired. Six 12-foot graders, 8 6-foot graders, 6 elevating graders, 3 steam rollers, 3 tractor-drawn rollers, 100 slip scrapers, and a few drags were purchased, and a number of drags were made. In the purchase of this machinery there was no time for making previous tests to determine the most suitable kinds and where a preference was indicated prospective delays in time of delivery resulted in the purchase of a machine that could be more quickly obtained. Provision was made for the hiring of as many Mexican laborers and teams as could be effectively used, the maximum force at one time being 800 laborers and 250 teams, in addition to the troops. In the Colonia Dublan sector, which extended about 10

miles north of Dublan, local labor was readily obtainable. In the two upper sectors, no local labor was obtainable and arrangements were made to obtain what was required from El Paso. The graded road was to be built 26 feet wide with ditches 1½ or 2 feet deep, with no shoulders and with the crown about 6 inches above the original ground level and was to be ultimately top-dressed with the best available material. The object was to get a road so that the trucks could run on any section of it and several series of roads could be formed if necessary.

As a result of the experience in roads up to this time,

Building the graded road.

moral support for the wet weather road was made noticeable by its absence, and as the work progressed the resulting pile of dust destroyed most of the optimism the previous experience in roads in Mexico had left. The road work was in the charge of Maj. Lytle Brown, Corps of Engineers, and it is a tribute to his perseverence to state that the apparent hopelessness of the proposition probably added to his interest in the project.

The road had been divided into three sectors for the pioneering work and the same divisions were retained. The first sector extended from Columbus 46 miles south to a high pass, which is 26 miles north of Ojo Federico; the second sector 56 miles south to

Corralitos Station; and the third sector 75 miles south to El Valle and included also the dry-weather road from Dublan, 24 miles north to Vuelta de Alamos. Company E was assigned the first, Company G the second, and Company H the third sector, and in addition to building the wet-weather road the pioneering work on the dry-weather road was continued. The enlisted men of the battalion were used as foremen, in charge of the tractors, scrapers, drags, etc., and the laborers were Mexicans employed at $1 per day and subsistence. The cooks as a rule were white, and a few white foremen were hired. The use of the enlisted men in the capacities mentioned proved very satisfactory. In addition to the 164 men per company in each sector, the average number of laborers employed in all the sectors varied from 300 to 800, with a maximum of 250 native teams. In view of the possibilities of attack, a guard of 10 men was required with each working party. The guard was furnished from the engineer soldiers, who, as a rule, carried their rifles on the work, and by details from the infantry and cavalry stationed along the line of communications. The tools used were those provided in the division engineer train. They are small and are not intended for continual use on heavy work, but they did very well for the short statured Mexicans.

By the 1st of September the crowned road and drainage was practically completed to a point 10 miles south of Dublan. All arroyo crossings had been prepared from there to El Valle and in addition the 24-mile stretch from Vuelta de Alamos to Dublan was top-dressed. Some top dressing had been placed on the sandy stretches in all the sectors, particularly on a 4-mile stretch north of Ojo Federico and on a 10-mile stretch north of Corralitos Station. The rainy season so far had been a disappointment. There had been barely sufficient rain to make the graded road passable, but the dry-weather roads had by this time become impassable and the graded road was the only available route. Being built without any binder, the compacting process was a slow and laborious one. Each truck train that passed destroyed the road and each time it was again rebuilt with graders and drags. The rollers were given a thorough try-out, but were gradually discarded as the drags began to prove their efficiency. With the continued rains, especially some heavy ones in the latter part of August and first part of September, the effect of the compacting by the trucks and the dragging became more pronounced and a comparatively smooth dirt road gradually developed. In this con-

dition the procedure after each rain was to drag the road as soon as it had dried sufficiently and to drain any ruts or low spots when water had collected. Occasionally, when a truck train had passed too soon after the rain, it was necessary to regrade it. During the remainder of the rainy season to about the 21st of September, at which time Major Brown was relieved by Lt. Col. M. L. Walker, Corps of Engineers, the road problem was a simple one and it began to be considered that the wet-weather road might be maintained through the winter months with the occasional rains that were expected. The last week in September and the first week in October with dry, hot, windy days, however, were suffi-

The compacting process was a slow and laborious one.

cient to reduce the crowned road to its impassable condition previous to the rainy season and the dry-weather pioneered roads were again used. The rainy season had apparently passed and the graded road was again being prepared when, on October 12, there began a soaking three days' rain. Both the dry-weather roads and the wet-weather road were impassable to truck trains. By the 16th, the graded road had been put in condition so that the trucks could travel it, and shortly after a satisfactory dirt road had again been prepared. To save the road, in order to avoid any future delay due to rain, the trains were shifted to the dry-weather roads as soon as they dried out.

Up to this time a new system of maintenance on a pioneered

road had been gradually developed. It consisted essentially in grading out the ruts with a tractor and a large grader, rather than attempting to fill them. This results in a sunken road and permits the use of hardened virgin ground without a continual excavating and clearing out of new roads. These sunken roads with no drainage naturally are not suitable for wet weather, but with the graded road, specially provided for this condition, the problem of making passable roads under the conditions presented may be considered solved. The sunken, or "shaved" road, as it was called, is a decided departure from the usual road-making principles. It was expected at first that new roads would have to be frequently opened,

The graded road being cut up.

but from October, when they were first started, to the withdrawal of the expedition in February, 1917, one road was sufficient. In places, it was scraped to a depth of from 1½ to 2 feet, but the average depth was about 1 foot, with an average width of 16 feet. The amount of material that had to be scraped off in order to keep the road in good condition was surprisingly small. During the winter the moisture is retained by the ground for much longer periods of time than in the hot, dry, summer months, and it is probable that it would require considerable more scraping, with a consequent necessity for more frequently opening up new roads in summer, over what it required in this case.

One feature that was of considerable assistance in preserving the road was the control of the traffic. Up to October, the speed of the trains was not controlled nor the roads to be used prescribed. In October, however, the maximum speed was limited to 12 miles per hour and the Chief Engineer Officer was given authority to prescribe the roads to be used and even to stop traffic for short periods of time after heavy rains.

In the actual construction of the graded road there were few points of interest, once the working force was organized. Particular care had to be taken with the drainage, especially at the

The sunken or "shaved" road.

water crossings. A large number of corrugated, galvanized iron culverts in sections were used. They were easily transported and readily placed. Some wooden culverts were built and a number of paved crossings were constructed. These pavements on the graded road were 12 feet wide and were made of two-man stones carefully laid on a prepared bed and with the interstices packed with spalls. Only the most careful work held up under the heavy traffic. The paved crossings were not favored by the drivers and travellers on the trains, but they served a purpose not foreseen in reducing the speed of trucks and in requiring more careful driving. Considering the damage to an earth road by heavy truck traffic, this is an

important feature. The paved slopes should not exceed very much a 6 per cent grade nor be too narrow at the bottom. In the deeper crossings a heavy rainfall makes the crossing impracticable, but since traffic at this time practically destroys the road the few hours delay caused is an advantage.

The experience with the road machinery was rather definite. Of the six types of tractors tested, four were of the rear-wheel-drive type, which were easily stuck in sand, mud, or soft-going and were finally discarded. The other two types were the centipede heretofore described and the 75-horsepower Holt caterpillars. The caterpillars, the type of the so-called British "tanks," were a decided success. The 12-ton machines have a bearing pressure on soft ground of 7 pounds per square inch and can negotiate most any kind of country with a load. In addition to their regular road work, they were continually used to drag out the trucks and other tractors that had been stuck. Considerable difficulty was, however, first experienced with break-downs and repairs, until an expert from the factory was provided, after which they were kept in almost continual operation. The centipede type was constructed of poor materials and was probably the least useful of those tried out. A large number of trucks were required for the small scrapers, drags, water wagons, dump wagons, transportation of supplies, etc. The Jeffery, 4-wheel drive, brake and steer with the interlocking differentials, proved the best for the work required of them. Except in the deepest sand and in mud, in which they sank to their axles they could be relied on to keep going. Two trucks were sufficient to haul a small grader with a 6-foot blade and one handled an 8-foot drag with ease. This, together with their use in pulling the supply trucks out of difficulties, was the hardest kind of work for them and was probably to a large extent responsible for the continual repairs required. There seems to be little question, however, but that the mechanical difficulties could be decreased considerably by an improvement in material and probably in design.

The steam rollers, as stated before, were of little advantage, and were discarded. The type of roller used had too high a center of gravity and was easily tipped over. The cost of transporting coal made their operation decidedly uneconomical, considering the results obtained. Under the conditions in this section, where coal is scarce, only gasoline or oil driven engines should be used. The tractor-drawn rollers had the same defect in design, with too high a center of gravity. The large graders, with a 12-foot blade, proved

to be good road building machines. They were ordinarily drawn by caterpillar tractors, though they were sometimes used with four Jeffery trucks. The same graders with a 6-foot blade were too light for road construction, but gave good service in the maintenance of the graded road. There is some doubt as to the advisability of purchasing so light a grader, for most of the maintenance work on the graded road can be done by a drag and the heavy graders are required on the sunken pioneered roads. A number of wooden drags of the ordinary type, with a cutting edge of iron or steel on the front runner, were made and gave satisfactory service. Several drags were purchased, but they were

Trucks passing through the canyon.

not any better, if as good, as those made in the field. As a result of the experience on the road in Mexico, the types of road machinery that gave successful service were the 75-horsepower Holt caterpillar tractors, Jeffery trucks, large 12-foot blade graders and the road drag of the type shown in the U. S. Department of Agriculture Bulletin No. 597. For handling material for top surfacing and building grades, ½-yard gas or oil engine shovels or drag lines would have been of considerable service and their purchase fully justified.

It has been proven by the experience in Mexico that trucks can be used for the supply of a force in the field. However, truck

trains run on dirt roads are not economical propositions. As stated in the beginning of this article, the object of the expedition, up to the time of the Parral affair, was to capture Villa, and no method of transportation available could have replaced the trucks. They served their purpose and did it well. Upon the establishment of more settled conditions the use of other kinds of transportation were considered, but no change was made because of the fact, hard to appreciate now, that at no time while the expedition was in Mexico was it believed that it would remain three months longer. This, in itself, eliminated from consideration the construction of a railroad, or even of plank or metalled roads, for a force of the size of the expedition. Dirt roads and animal transportation are an economical combination from the standpoint of the road, but in this case the great distances, the lack of water, and the necessity of hauling all forage made the use of this form of transportation impracticable. The caterpillar tractors furnish, fortunately, a solution; they require very little road construction, and the experience gained with them in the road work in Mexico showed their suitability for the transportation of supplies. Wheel tractors are not considered in the comparison for the reason, as before stated, that they were easily stuck in mud and deep sand, which conditions were frequently encountered.

The Mexican laborers, contrary to the general impression at the beginning, were most satisfactory. They were good workers and were easily controlled. Before they were allowed to be sent into Mexico, it was necessary to put them through a delousing process, which consisted of clipping their hair and giving them gasoline baths. After suitable accommodations for this purpose were provided, there was very little objection on their part to the cleaning process and the laborers that were held at Columbus made it a practice, voluntarily, to bathe frequently. The fine physique of these men, as observed when they were going through the cleaning process, was a considerable surprise. They were, as a general rule, well proportioned with well developed physiques which their ordinary garb concealed.

Considered as a whole, the experience gained by the engineer troops was valuable. Their work in the opening up and maintenance of roads was of primary importance for the supply of the expedition, and they gained experience in road building and in the handling of road machinery and labor under most adverse conditions. As the work progressed, the value of localizing re-

sponsibility became more and more apparent, and when the construction work was completed and maintenance work begun, the assigning of a small section of the road to one man with the necessary laborers and machinery had the result of giving him a proprietary interest in that section of road and a desire to make it better than any other similar section.

COMMENTS *by* MAJ. LYTLE BROWN, *Corps of Engineers.*

When the raid on Columbus, New Mexico, was made on Thursday, March 9, 1916, by an armed body of Mexicans, Companies E, G, and H, and Battalion Headquarters of the Second Battalion of Engineers, were stationed at San Antonio. Detachments of the battalion were distributed along the border on survey work from Brownsville, Texas, to Nogales, Arizona, and one detachment was at Fort Sill, Oklahoma.

It became evident on March 10 that an expedition was to go into Mexico from somewhere near El Paso or Columbus. It was recognized at once by the authorities that, if dismounted troops were to be included in the expedition, a pioneer battalion of engineers would be as useful on the expedition as any other body of foot troops which could be sent. Accordingly, the above-named battalion of engineers was included among the organizations that were to go in the expedition. All detachments were at once ordered by wire to join their respective companies en route to El Paso or Columbus. Two companies, E and H, and battalion headquarters, were ordered to Columbus, and one, G, to El Paso. The base selected for the expedition was at Columbus, N. M. Company G was stopped at El Paso for use on the railroad south from that point, in case either of the two lines should be taken over by the American authorities. Very soon it became evident that the railroad was not to be taken over by the Americans, and Company G was moved to Columbus and thence into Mexico.

The movement from San Antonio to Columbus was made with a fair degree of celerity, considering the large amount of equipment that was taken (Equipment C, Tables of Organization) and the dispersed situation of the command, as well as the shortness of the warning. It was accomplished by the afternoon of March 12, except for a later arrival of one or two detachments.

There were two points of departure for the expedition, viz, Columbus and Hachita, N. M.; the 9th, 10th, and 7th Cavalry going in from the latter place via Calbertsons Ranch, while the 13th Cavalry, 11th Cavalry, 16th Infantry, 17th Infantry, 24th Infantry, 2 battalions 4th Field Artillery, 2 batteries 6th Field Artillery, 2d Battalion of Engineers, Signal Troops (Tel. Co. H), Ambulance Co. No. 3 and other detachments, went in at Columbus.

The first troops from Columbus, with the 13th Cavalry in advance, moved south from Columbus on March 15. The commanding

officer of engineers did not succeed in getting authority to move the pioneer troops out at the head of the dismounted column, though an engineer officer and a detachment of mounted men from Company H moved out with the 13th Cavalry. The knowledge of the conditions to be found across the border, as possessed by the senior engineer officer, was limited by the memorandum which had been prepared and issued by the General Staff in the form of road notes. These notes were very useful in so far as they went, but they were far too meager to answer any questions as to engineer operations, especially such as were entailed by an expedition of the character actually presented. The best of written notes are not of much use unless the maker of them knows the precise nature of the operations which they are designed to guide.

Not till March 16, at 2 p. m., did any of the engineer troops, except the mounted detachment aforementioned, move. Company H on that afternoon moved to Gibsons Ranch, 14 miles west of Columbus, under orders to cross the border at that place and move south to Boca Grande and thence to Ascension, to reconnoiter the road, report upon its suitability for truck train transport, and pioneer it with a view to such traffic. This company did as directed, and at a point 17 miles south of Boca Grande, called El Espia, gained the head of the column of foot troops and maintained this position, pioneering the road as it went, till the advance reached Namiquipa, the point later chosen for the advanced base.

Meanwhile the other two companies, E and G, were brought south. It was seen that the keeping open of some kind of road was essential, so the line from Columbus to San Antonio, 75 miles south of Namiquipa, was divided into sectors and assigned to the three engineer companies, who were instructed to keep the road open by pioneer methods and to reconnoiter for new locations. As soon as possible two automobile trucks per company were assigned for the purpose of rapid transport for working parties.

The road to be used by the auto truck supply trains—that is, Columbus to Gibsons Line Ranch, thence to Boca Grande, El Espia, Ascension, Ojo Federico, Colonia Dublan, was examined by the engineer officer on the passage of the first dismounted troops—that is, Company H, 2d Battalion of Engineers. It was seen at a glance that this road could not stand traffic in the dry season, on account of great stretches of soft ground unmixed with either gravel or clay, and underlaid wit large mesquite roots which destroyed the homogeneity of the road bed. It was also seen that in the rainy season the road would be impassable for many miles at a stretch on account of mud, and that the Casas Grande River, both at Boca Grande and at Ascension, would at times be over the road by several feet. Especially at Ascension was this river crossing very objectionable, as the flat valley there at times of high water was overflowed to a width of half a mile. Even in the dry season irrigation ditches sometimes broke into the road at Ascension and made passage for a distance of half a mile very difficult.

At the first opportunity the matter was laid before the Commanding General by the engineer officer verbally. This was on March 23, at Colonia Dublan. At this time it became clearly apparent that an automobile was necessary for engineer staff duty, and one was procured promptly.

The next verbal conference with the Commanding General was at San Geronimo ranch, 20 miles south of Namiquipa. This was on April 7. It was decided to ask for funds to prosecute road work, or rather to buy materials with which to work. The idea was to lay a plank tramway over the soft sections of the road. Funds for this purpose were accordingly requested. A reply was received at San Antonio on April 10, that on account of the possibility of better arrangements for the supply of the expedition, the funds were not allowed.

At all times the pioneer treatment of the road was being prosecuted with all the means and all the vigor at command. Infantry details were furnished, particularly from the 24th Infantry, and both officers and men of this command did all that could reasonably be expected.

About the middle of April, through a round-about arrangement, supplies began to arrive at Colonia Dublan by rail, and a few carloads were obtained at San Antonio by rail from Chihuahua City; but it was understood that these few cars about cleaned out the latter place. At all times it was fully realized that supplies by rail were likely to cease at any time, for one reason or another. Aside from the possible interference by Mexican authorities, the railroad was in such condition that the torrential rains of June to October might be expected to put the line out of use for a more or less extended period of time.

From a knowledge of the conditions to be met, and these were ascertained at the earliest practicable moment, it was seen that a field engineer depot would be necessary at Columbus. Accordingly, an engineer field depot was organized at Columbus on March 25 from the personnel of the 2d Battalion of Engineers. No funds were on hand, but knowing that the equipment of the engineer train of the 2d Division was at Fort Leavenworth Depot, that equipment was secured from the depot officer without delay, and the work of making estimates and securing quotations on other material was begun at once. Funds were received after a time, and later other depots were organized at El Paso and other places through the efforts of the engineer authority at headquarters, Southern Department. The field depot at Columbus later drew most of its supplies through the agency of the engineer depot at El Paso. Once these depots were organized, there was no question as to the machinery of supply. The atmosphere cleared at once in so far as engineer staff operations were concerned.

As the season of rains approached, there were many opinions expressed, and, as Captain O'Connor says, it was almost universally thought that the supply overland would be impossible. This

was forecasted by the statements of natives and Americans who were well acquainted with the conditions prevailing in the country. From his observations as to the impossibility of building any earth or macadam roads at all in the dry season, and knowing that the rainfall in that country aggregated only 15 inches in the year, and also knowing the rapidity with which a well drained graded earth road could be put through, as well as the rapidity with which it could be reworked, the engineer officer thought that conditions could be greatly improved during the rainy season. The Commanding General was the only one who had the optimism and foresight to agree to this. One of the ranch managers, American, at Colonia Dublan told the engineer officer that during the rainy season a horse would have difficulty in crossing some of the upland mesas traversed by the truck road.

The decision in the last of May was to build for rainy season use a graded road to Dublan from Columbus, and measures were taken to do it. Much difficulty was experienced in beginning to take these measures and in carrying them out, but the difficulties were such as might have been avoided, and will be avoided in future by an efficient engineer staff liberally provided with funds.

No grading was thought necessary in that stretch of road located between Colonia Dublan and El Valle, 65 miles. By the excellent reconnaissance work of the officers of Company G in the month of May, that route was located on hard, well drained ground at the foot of the range running south from Chocolate Pass via San Joaquin, and this proved to be, with only the ''lick-and-a-promise'' methods of pioneer work, the best piece of going that was found. The reconnaissance work of April and May placed the route from Columbus to Dublan on the best available ground.

Miscellaneous Notes.

Adjustable Sluice-Gate with Automatic Control.

NYHOLM SYSTEM.

BY

Mr. GEORGE BENDIXEN.[1]

This is a brief description of a device employed at a dam near Besigheim in the Neckar Valley to maintain a uniform water level.

The problem demanded the maintenance of a practically constantly uniform upper pool level, a rise of more than 1 inch (2½ cm.) to be prevented. To accomplish this a gate was constructed, in dimensions 8.00 meters wide and 3.00 meters high. It is composed of two parts: the lower, 1.80 m. high, fixed; and the upper, 1.20 m. high and of the full width of 8.00 m., arranged to swing on hinges connected to the lower part of the gate. This movable crest (see Fig. 1) is connected at each end by means of chains and overhead pulleys to circular plates (system Nyholm) which operate in cylindrical shafts 1.3 m. in diameter in the concrete retaining piers.

The plates are subjected to the pressure of the upper pool, while below them are culverts 40 cm. in diameter leading to the lower pool, and connected also with the upper pool. The latter connection has a funnel-shaped opening extending slightly above the normal water surface. A small pipe "*b*" leads to the culvert, and is intended to permit the escape of air which may be carried with the water through the pipe "*a*."

Normally, the plates are held down by the water pressure due to the difference of head in upper and lower pools, and hold up the swinging gate by the chains. However, if the head water level should rise, for instance, due to stopping one or more of the water turbines of the factory upstream, water would flow into the

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[1]51 E. 42d Street, New York City, American agent for Nyholm patents.

funnels of pipes "*a*" and tend to equalize the pressure on the upper and lower faces of the plates in the shafts—because the water enters more rapidly that it is allowed to escape through the small lower outlet which, besides, is equipped for valve regulation.

The plates will consequently rise as the water pressure against the movable crest forces it down. The movement is, however, slow and gradual, because the plates in the shafts act as brakes, having to overcome some water pressure in rising.

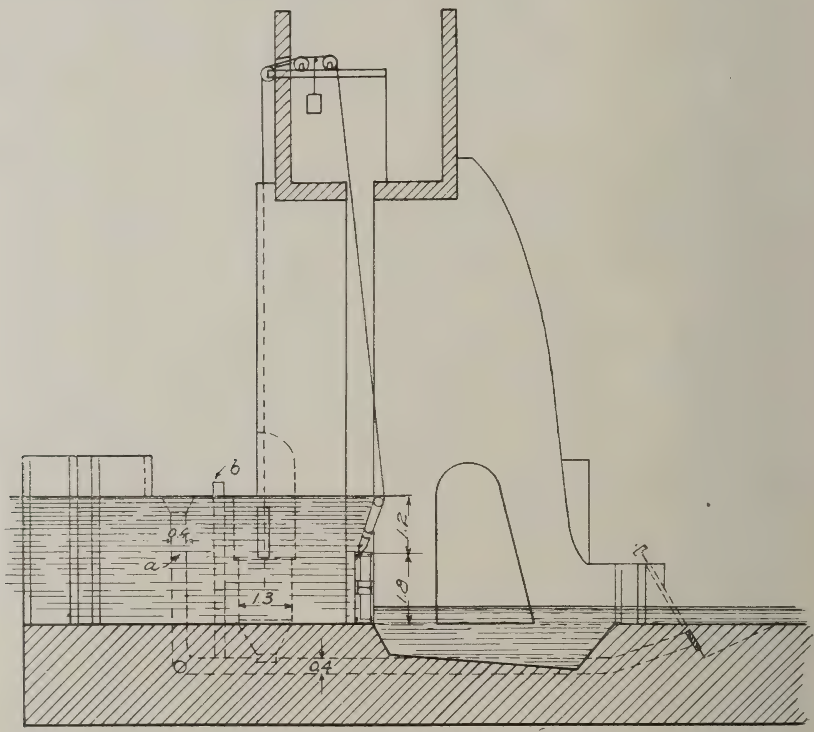


Fig. 1.

As soon as the upper water level drops to normal as a result of overflow, the funnel of pipe "*a*" appears above the water and further influx of water is prevented. The plates again get full pressure, and are forced down, drawing the gate up into normal position. The plates have no seats, but hang suspended in the shaft, moving slightly up and down continually. They do not fit tightly in the shaft, the water escaping past them and being carried away by the culvert to the lower pool.

This device was constructed by the Gustavsburg branch of the Augsburg Nuernberg Engineering Works, for the Oil Mfg. Co. at Besigheim on the Neckar, supervised by royal councilor, Mr. Maurer, of Stuttgard. It has been in operation for over three years without interruption and automatically responds to even the slightest change of water level. A rise of less than ½ inch is sufficient to lower the movable crest gate; this never drops very much, but plays constantly forth and back. (American Patent No. 89970; German Patent D. R. P. 220835.)

Fig. 2. Sluice-Gate at Besigheim, System Nyholm.

Nyholm System of Lock Operation.

BY

Mr. George Bendixen.

This is a brief descripion of a lock filling and emptying device and of a gate maneuvering device known as the Nyholm System, as applied to a lock on the Rhine-Elbe Canal near Minden, Germany, by Gehbauer Brothers, Berlin, for the Royal Prussian Government.

DEVICE FOR FILLING AND EMPTYING LOCK CHAMBER.

This works on the siphon principle, using compressed air for part of its operation and vacuum for part. For neither compressed air or vacuum is any container required outside the siphons themselves, nor is any extraneous power needed to provide them, the pressure of the water in the upper pool alone being utilized. The emptying and filling culverts, together with an exceedingly simple arrangement of pipes and cocks, constitute the entire device. It can be operated by one man, who can also operate the lock gates by the Nyholm System, as will be shown later.

Emptying the Lock Chamber.

The arrangement for this consists solely of—

1st, a siphon on either side of the lock;
2nd, an air pipe connecting these siphons;
3rd, a branch from this air pipe to the open air;
4th, a cock for opening and closing the branch pipe.

The siphons have their highest point below the upper pool level and form parts of the emptying culverts. In Fig. 1 *a, a′* is the emptying culvert, *b* the siphon, *c* the connecting air pipe to the opposite emptying siphon, *d* the exhaust branch, *e* the cock, *f* the lock chamber, and *g* an air pipe leading to the filling siphon, the use of which and of cock *h* will be described later. The operation is as follows: If, while the lock chamber is being filled the cock *e* is kept closed, the pressure of the rising water in the chamber will necessarily compress the air in the siphon. The siphon is of such dimensions that when the lock chamber is full the water in the siphon leg *ab* can not reach the point *j* by some distance, as *k*. The compressed air forms an effective seal. To empty the lock chamber, provided no additional water enters it, it is necessary only to open the cock *e* when the air in the siphon head will drop to atmospheric pressure, the water will rush over the point *j*, establishing siphonic action, and such action will continue until the lock chamber is emptied. It is, of course, necessary that the cock *e* be closed immediately after the air in the siphon head has been reduced to atmospheric pressure, in order that the siphonic action may continue until the water levels in the lock chamber and in the lower pool are equalized. When the lock chamber is empty we have, therefore, the emptying siphon full of water.

Filling the Lock Chamber.

The arrangement for this consists also of a siphon on either side of the lock forming parts of the filling culverts, but in the cases of these siphonic action is established when the lock is to be filled by reducing the air pressure in the siphon head to below atmospheric. This is accomplished by the agency of the water in the emptying siphons, by means of the pipe *g*. It will be recalled that when the lock chamber has been emptied, the emptying siphons remain filled with water. Should, now, a cock *h* which had been so set as to close the pipe *g* before the filling of the lock chamber be now open-

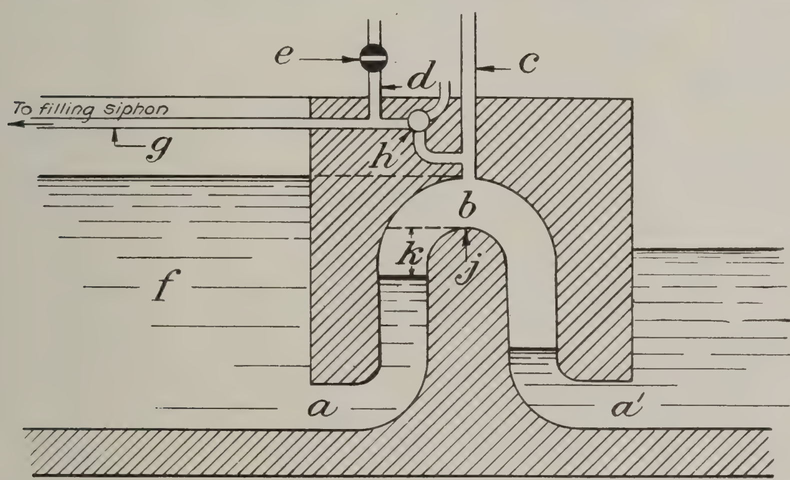


FIG. 1. Emptying siphon. (vertical section)

ed (cock *e* still being closed) the weight of the water in the legs of the emptying siphons will reduce the pressure of the air in the head of the filling siphons to below atmospheric pressure. This will establish siphonic action in the filling siphons, which will continue until the water in the lock chamber is at upper pool level.

That the lock chamber may be completely filled, it is necessary that the emptying siphons should be sealed by compressed air, as described above, in order that they may function properly. It is also necessary that siphonic action in the filling siphons may be interrupted when the lock has become filled, in order that such action may not be resumed when the lock chamber is to be emptied. Both of these are accomplished by means of the cock *h*. The com-

plete cycle of operations to empty and fill lock is as follows (lock full, cock *e* closed, cock *h* closed):

1. Open *h* and *e* simultaneously.

   This admits air to filling siphons, preventing further siphonic action there.

   It also allows compressed air to escape from emptying siphons, establishing siphonic action and beginning to empty the lock.

2. Close *h* and *e* simultaneously, and at once.

   This allows siphonic action to continue to empty chamber. (The lock being empty, the upper siphons have air at atmospheric pressure, the lower siphons are filled with water.)

3. Open *h*.

   This causes the air in the filling siphons to be reduced below atmospheric pressure, due to the weight of the water in the legs of the lower siphon. Siphonic action is begun in the filling siphons and the lock chamber begins to fill.

4. Turn cock *h* so as to admit air to *b*.

   This furnishes the air to form the compressed air seal in the emptying siphons.

5. Turn cock *h* so as to close pipe *g*, and also communication with the outside air.

   This allows the rising water in the lock chamber to compress the air in *b*, and the cycle is complete.

This device would then call for a cock *e* capable of closing and opening pipe *d*, and a 2-way cock which can (1) provide a passage from *b* to *g*; or (2) provide a passage from *b* to the open air; or (3) close all communication from *b* to *g* and from b to the open air.

The above is illustrative only. Actually only one cock is used, and that a 3-way cock, at *h*, which performs the following functions: (1) connects *b* and *g* with the outside air; (2) connects *b* with *g*; (3) connects *b* with the open air, closing passage to *g*; and, finally (4) closes all communication between *b*, the pipe *h* and the outside air.

The cock is operated by a lever carrying an indicator moving over a dial on which the numbers 1, 2, 3, 4 and 5 are placed in order. To empty the lock the indicator is moved from the position "closed" to 1, thence immediately to 2; to fill the lock the indicator is turned in order to 3, 4, 5 and then to position "closed."

It is necessary that the lock be filled the first time by auxiliary valves, but these are needed in any event as emergency valves.

This method of filling and emptying lock chambers has the advantage of using no moving gates or valves, devices always subject to injury and difficult to repair. The only moving parts in the Nyholm System are the cock and the lever to operate it, and these and the air ducts are always easily inspected and repaired. The emptying siphons are so low that they may be wholly below the general surface of the lock walls.

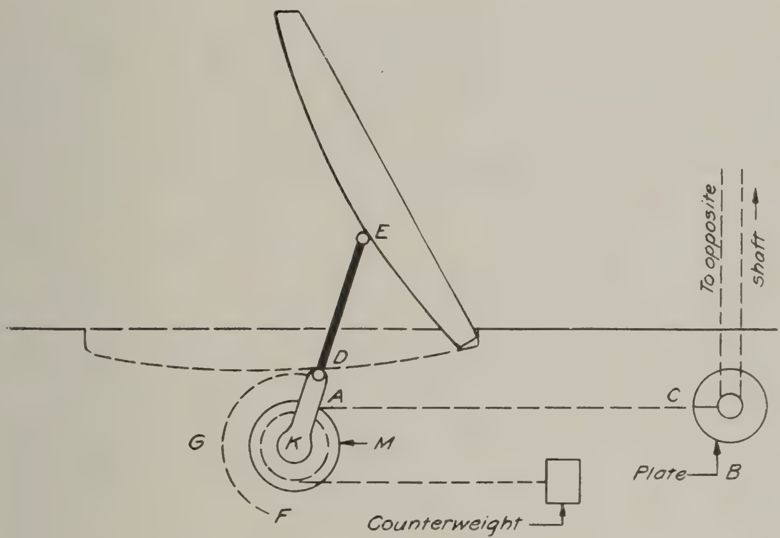


FIG. 2. Gate maneuvering device. (plan)

The siphons will function properly with as small a difference of head between pools as 16 to 20 inches. Waves in locks and pools have no injurious effect on their operation.

DEVICE FOR OPERATING THE LOCK GATES.

In the particular lock under consideration the upper gate is a "tumble" gate, a single leaf, hinged at the bottom to the lock floor, on which it rests when open. The lower gate is of the mitering type.

For the single upper gate leaf and for each of the leaves of the lower gate there is provided a plate, suspended in a cylindrical shaft and connected to its gate leaf by means of a chain. Move-

ment of the plate, with corresponding movement of the gate leaf, is effected by water pressure, regulated by a cock, the shaft being connected with both upper and lower pools. The principle is described in the preceding article on the Nyholm system of automatic sluice gate control, the only essential difference being that in this case the movement of the gate leaves is controlled by means of a lever operating the water valve. Return movement of the gates is effected by means of counterweights in the case of the lower gate, and by the dead weight of the gate-leaf itself in the case of the upper gate.

The two shafts pertaining to the lower gate are connected by a pipe to transmit pressures. There is but one cock required to operate both upper and lower gates, and this can be so arranged that the same lever which controls the air cock used in the Nyholm system of filling and emptying the lock chamber can simultaneously control the water cock to operate the gates. Thus, one man can perform both operations.

The Lower Gate.

The leaves of this gate are closed by means of spars D-E (see Fig. 2), attached at one end to the leaves and at the other to an arm K-D. The arm K-D is rotated about K as an axis, while the gates are being closed, by the chain A-C attached to the plate B, which has for this purpose been subjected to upper pool water pressure on its upper side only, the water cock having been set in the appropriate position. The counterweight is raised at the same time. On the admission of upper pool water pressure to the lower face of the plate, the lower gates will swing open, due to the counterweight, provided the lock chamber is empty—earlier movement being prevented by the water pressure on the gates.

It will be noted that the travel of the gate leaves at the beginning and end of their swing is slow, as it should be to avoid slamming, and also that the arrangement affords the relatively greater power required to begin the movement of the gate leaves.

The Upper Gate.

The plate operating the upper gate has upper pool water pressure, both above and below it, while the chamber is being filled. When the chamber is full the gate drops of its own weight. To close the upper gate its plate is subjected to upper pool water pressure on its upper surface only, causing the plate to fall, which raises the gate leaf.

The Water Cock.

The water cock is so arranged as to admit water from the upper pool to the shafts both above and below the plates, and also to connect the lower parts of the shafts with the lower pool when it is required to relieve the plates from upward pressure. The water cock requires but one position for each operation of the lock in passing a vessel, which can be illustrated by the following examples:

(*a*) Chamber empty, lower gates open, a vessel enters the lock—

The water cock is set at position *one*. As a result of this, the lower parts of the shafts pertaining to the lower gate are connected with the lower pool and the space above with the upper pool. The upper pool water pressure now forces the plates down, closing the lower gate and raising the counterweight. In the meantime, the plate of the upper gate has upper pool water pressure on either side.

The lock is filled, in this particular case, by the Nyholm siphon method.

The lock being full, the upper gate falls of its own weight and the vessel passes out of the lock.

(*b*) Chamber full, upper gate open, a vessel enters the lock—

The water cock is set at position *two*, whereupon the upward water pressure on the plate operating the upper gate is removed through opening of communication with the lower pool. The plate is forced down, closing the upper gate by means of the chain. In the meantime, the plates of the lower gates have upper pool pressure on both sides.

The chamber is emptied, by siphon or other method.

When the chamber is empty, the counterweights open the lower gate leaves and the vessel passes out of the lock.

Durability of Timber in Cleveland Breakwater.

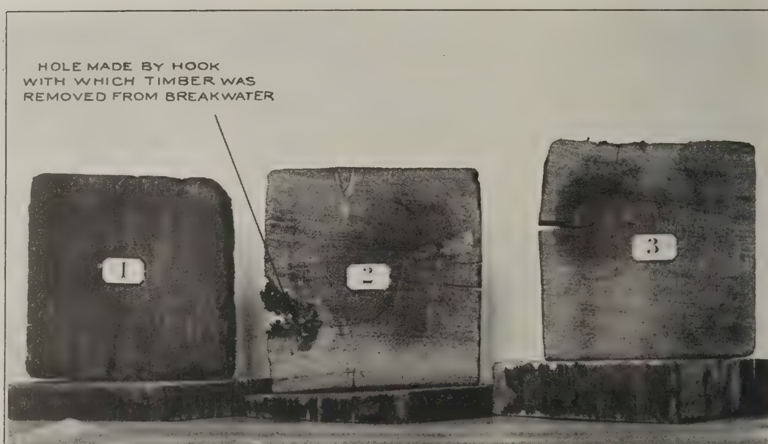
BY

Maj. P. S. Bond,
Corps of Engineers.

In connection with the repair of the timber crib breakwater at Cleveland Harbor, Ohio, by rebuilding the superstructure with stone in 1916, it was necessary to remove some of the heavy timber of which the original superstructure was built in 1891-1893. The drafting of specifications for this work raised the question as to how much of the timber structure could be left in place with

assurance that it would be practically permanent. The original structure was built of white pine timber.

The specifications under which this work is being done require "that the timbers composing the outer walls of the crib on the harbor face and the southerly half of the cross walls shall be removed to 1 foot below mean lake level, or to the top of the first timber lying entirely below that level." Under this specification the elevation of the top of timber left in place might be nearly 2 feet below mean lake level, and the average probably about 18 inches. In order to show the relative condition of the timbers re-



East Breakwater, Cleveland Harbor, Ohio.
1. Cross-tie, entirely above water level;
2. Cross-tie, at water line;
3. Cross-tie, entirely below water level,
Crib constructed 1893; timber removed 1916.

moved from various portions of the structure, samples have been taken as follows:

1. Entirely above mean lake level;
2. At mean lake level;
3. Entirely below mean lake level.

Timber located entirely above mean lake level (Sample No. 1) has suffered some deterioration on the exterior surface, but not to any considerable depth, as indicated by the fact that the present dimensions of cross section are not more than ½ inch less than the corresponding dimensions of a piece which had been entirely submerged (Sample No. 3), which has retained practically its original cross section, as is indicated by the fact that the dressed surfaces

can still be seen. The interior of this timber (Sample No. 1) is as good as new.

Sample No. 2 indicates that a timber at the elevation of mean lake level has suffered practically no deterioration in a period of about twenty-four years.

It is believed that some economy in construction can be effected by modifying the requirements so as to provide for leaving the old timber in place above mean lake level, unless the nature of the reconstruction work makes its removal necessary. This timber, if left in place on the harbor side, will serve as a fender so long as it lasts and, in view of the fact that no detriment can possibly result therefrom, it appears unwise to expend funds for its removal.

A modification in policy will be recommended for repair of timber crib breakwater to be undertaken next season, for which specifications are now being prepared. The condition of the breakwater appears to furnish additional evidence that timber is not subject to deterioration at mean lake level, and that even a little above that level it remains sound for many years.

Engineer Exhibit at Plattsburg, 1916.

An engineer exhibit consisting of models and full-sized structures was built at Plattsburg and used in connection with the lectures on military engineering, given to the attendants at the training camps.

The following list of articles in the exhibit may be of use to other officers charged with imparting instruction at training camps:

RECONNAISSANCE.

1. Contoured sand box, model and map of same.
2. Combined azimuth and vertical angle instrument.
3. Models to illustrate road sketching.
4. Exhibit of reconnaissance instruments.
5. Geological survey maps.
6. Conventional signs.

BRIDGES AND RIGGING.

1. One-man raft, full size.
2. Barrel raft, full size.
3. Flying ferry, model.
4. Rope ferry, model.
5. Trail ferry, model.

6. Reserve train ponton bridge and landings, portable and non-portable, models.
7. Holdfast, full size.
8. Deadman, full size.
9. Single-lock triple-sling bridge, model.
10. Two-legged trestle bridge, model.
11. Pile trestle bent, full size.
12. Framed trestle bent, full size.
13. Advance guard ponton, model.
14. Two, three, and four-legged trestle bridge, model.
15. Suspension bridge, model.
16. Single lock bridge, model.
17. Ladder foot bridge, full size.
18. Double lock bridge, model.
19. Single lock, single sling bridge, model.
20. Board, with knots and lashings.
21. Board, with various types of blocks and tackles.
22. Trestle, 45 feet high, built up with rope lashings.
23. Shears, full size.
24. Gin, full size.
25. Spanish windlass, full size.
26. Barrel windlass, full size.
27. Portable field derrick, full size.
28. Field pile driver, model.
29. Model, illustrating Rees method of pile driving.
30. Gabion bridge, full size.
31. King-post truss.

DEMOLITION.

1. Complete demolition equipment.
2. Mule, packed with demolition equipment.
3. Examples of placing charges to fell a large tree, and connection for same.

OBSTACLES.

1. Portable barbed-wire entanglement, using long saw-horse trestle.
2. Abatis.
3. High, irregular barbed-wire entanglement, built in place.
4. Smooth wire entanglement, using three-legged trestle for supports, broken bottles, spiked boards, etc.
5. Cheveaux-de-frise with barbed wire, showing how same is used to barricade street.
6. Low wire entanglement.
7. Military pits.
8. Combination of 6 and 7.
9. Palisade.
10. Italian type portable wire entanglement.

11. Italian portable obstacle, made of iron rods.
12. Fougasse.
13. Land mine.
14. Four types of alarm signals.
15. Two types of flares.

TRENCHES.

1. Skirmish trench, showing method of constructing same, full size.
2. Traversed trench, standing, and bombproof cover trench, connected by zigzag communicating trenches. Scale, 4″=1′.
3. Simple standing trench, 1-foot command, full size.
4. Complete standing trench, 1-foot command, full size.
5. Strengthened Japanese type standing trench, full size.
6. Machine gun emplacement, present French type, full size.
7. Machine gun emplacement for 2 guns, full size.
8. Sand box, with models of various types of trenches.
9. Trench screened against aerial reconnaissance.
10. Deliberate entrenchment to resist field guns.
11. German trench with bombproof.

MINING.

1. Gallery with cases.
2. Gallery with frames and sheeting.
3. Shaft lined with casings, showing method of breaking out gallery.
4. Same as above, with frames and sheeting.

TRENCH ACCESSORIES.

1. Loopholes, concealed and unconcealed; 5 types.
2. Head-cover, using logs and fascines.
3. Trench periscope.
4. Chicken-wire defense for hand grenades.
5. Hand grenades.
6. Trench mortar.

REVETMENT.

1. Fascines, showing how same are constructed.
2. Gabions, showing construction.
3. Pole revetment.
4. Hurdle revetment.
5. Sand-bag revetment.
6. Sod revetment.
7. Board revetment.
8. Straw mats, showing method of weaving.

A full-sized trench was revetted, showing different methods of revetting.

MISCELLANEOUS.

1. Field gun emplacements, 2 types.
2. Ballista for grenades.
3. Cross-bow for grenades.
4. Hut, brush shelter.

ROADS, FULL-SIZED SECTIONS.

Brushwood road in marshy soil.
Dirt road in firm soil.
Corduroy road.
Telford road.
Macadam road.

Errata, No. 43.

Page 4, line 18, "Fig. 14" should be "Plate I."
Page 4, line 23, "Fig. 15" should be "Plate II."
Page 4, line 34, "Fig. 14" should be "Plate I."
Page 8, line 13, "Fig. 15" should be "Plate II."

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FROM "ROBERT E. LEE, MAN AND SOLDIER," BY THOMAS NELSON PAGE; CHARLES SCRIBNER'S SONS. BY PERMISSION.

GEN. ROBERT E. LEE

1807-1870

Robert Edward Lee.

BY

Maj. WILDURR WILLING,
Corps of Engineers.

Robert Edward Lee was born on the banks of the Potomac at Stratford, Westmoreland County, Virginia, on the 19th of January, 1807. He was a son of Henry Lee, the ''Light Horse Harry'' of the Revolution, famous patriot, soldier, member of Congress, thrice governor of Virginia, and immortal eulogist of Washington. Robert's ancestors, the Lees and Carters, had been distinguished for many generations in Colonial history. Westmoreland County had given to America George Washington and James Monroe. The youthful Lee was brought up amid the glorious traditions of the Revolution.

When Washington was sacked and burned by the British, Robert, then 7 years of age, was residing in Alexandria, whither his father had moved in 1811. The lad was justly proud of his ancestors; but we search history in vain for any such signs and portents of coming greatness as are related by enthusiastic biographers of the youthful Napoleon. He was quiet, modest, studious, respectful of his elders, and devoted to his widowed mother.

Robert entered the Military Academy at West Point July 1, 1825, at the age of 18, and was graduated second in his class July 1, 1829, and commissioned a second lieutenant in the Corps of Engineers.

At the date of his entrance, the Military Academy had graduated just 428 cadets. These had not yet been tested in a great war; and the nation was unconscious of the quality of the material being developed on the banks of the Hudson. Cadet Lee was very studious. In the Corps of Cadets with him were many destined to great fame. While he was a ''plebe,'' there were in the first class such men as William H. C. Bartlett, Albert Sidney Johnston, Samuel P. Heintzelman and Silas Casey; in the second class, Leonidas Polk and Philip St. George Cooke. Charles Mason was the honor man of 1829; Joseph E. Johnston stood thirteen. In lower classes

were Alexander J. Swift, Francis Vinton, William N. Pendleton, John B. Magruder, Roswell Park, Andrew A. Humphreys, William H. Emory, Benjamin S. Ewell, Jacob W. Bailey, E. D. Keyes, John N. Macomb and Robert H. Archer.

West Point at that period was a very successful theological seminary with a leaning toward the old Established Church of England. Polk, Park, Pendleton and Vinton all became Episcopal ministers and took high position in the church. Bartlett, Church and Bailey won world fame in the peaceful pursuits of scientific investigation. Lee and Humphreys were famous in both war and peace.

To the soldier, and especially to the engineer officer, Robert E. Lee's life presents itself in three phases: first, as the engineer; second, as the staff officer in the Mexican War; third, as the independent commander of a great army.

The Board of Engineers for Fortifications submitted its first epochal report on our land defenses in 1820. Among the early works designed was the seven-bastioned enceinte of Fortress Monroe. Lieutenant Lee's first assignment to duty was on this work in his native State, where he remained until 1834. On June 30, 1831, he married Miss Mary Parke Custis, his boyhood friend, and granddaughter of Washington's step-son. By this alliance, he added to his already high social position and became a sharer in Arlington and other valuable estates.

From 1834 to 1837, Lee was assigned to duty as assistant to the Chief of Engineers of the Army, and resided at Arlington.

In 1837, shortly after promotion to the grade of First Lieutenant, Corps of Engineers, he was given his first assignment on river and harbor duty, being charged with surveys and works of improvement on the Upper Mississippi and on the Missouri rivers, with station at St. Louis, Mo.

The Rivers and Harbors Act of July 4, 1836, contained an item "For a pier to give direction to the current of the Mississippi River near the City of St. Louis, fifteen thousand dollars."

The project submitted by Lieutenant Lee, dated December 6, 1837, and based upon surveys made by him and Lieutenant Meigs, followed the general lines proposed by General Gratiot in 1834 for the removal of the bar in front of St. Louis, and was adopted by the War Department.

The trouble in St. Louis harbor arose from a division of the river channel in front of the salient point of the city by Bloody

Island. At that time, the greatest depth of water was in the western or Missouri channel; but the eastern or Illinois channel was constantly deepening, caving the Illinois shore, and threatening to eat into Cahokia Creek (a small stream parallel to and flowing into the Mississippi). To make matters worse, a long flat bar had made out from the foot of Bloody Island in a southwesterly direction to Duncans Island, near the Missouri shore. At extreme low water, steamboats coming from the south had to pass up the eastern channel and, turning the head of Bloody Island, drop down to the city landing.

To remedy this state of affairs, Lee recommended the closure of the eastern channel by a dam from the head of Bloody Island to the Illinois shore, and the construction of a longitudinal deflecting dyke, extending out from the foot of the island and parallel to the Missouri shore, to wash away the shoal connecting it with Duncans Island, as well as a portion of the latter island itself. The closure dam was to be 1,782 feet long, the dyke 3,000 feet long, both to be built 5 feet above low water. As an alternative to the closure dam, the designer proposed a dyke (afterwards adopted) extending downstream from old Venice, near the foot of Kerrs Island, towards Bloody Island for about 4,240 feet. Both the upper and the lower dykes were begun in the summer of 1838 and subsequently completed. They accomplished the purpose for which designed.

After leaving St. Louis, Captain Lee was charged for a short period (1840-1841) with the execution of surveys and plans for the improvements of the Ohio below Louisville and of the Lower Mississippi.

The interval between the fall of 1841 and the outbreak of the Mexican War in 1846 found Lee engaged principally upon the new fortifications at the Narrows, at the entrance to New York harbor. He resided at Fort Hamilton, and was given a number of details in addition to his other duties.

When the long expected Mexican War was ushered in with the Battle of Palo Alto on May 8, 1846, Capt. Robert E. Lee, Corps of Engineers, was 39 years of age; he was assigned as chief engineer of Wool's expedition. Palo Alto and Resaca de la Palma had been fought, the passage of the Rio Grande forced, and on the very day (September 23, 1846) that the engineers under Wool were leaving San Antonio, Quitman and Worth were knocking at the gates of Monterey. It must have seemed to Lee that he was destined to play a minor rôle.

He had under his direction Captains Hughes and Fraser and Lieutenants Sitgreaves, Franklin and Bryan. Wool arrived at Saltillo without meeting opposition. Just as his column was about to be offered an opportunity to show its mettle at Buena Vista, its chief engineer was transferred to the expedition against the City of Mexico.

The American troops landed at Vera Cruz on March 9, 1847, and completed the investment on the 13th. The successful siege operations were directed by Generals Scott and Totten; and no subordinate played a more conspicuous part than Lee.

General Scott and his staff, to which Lee was now assigned, left Vera Cruz on the 12th of April to join his advanced divisions under Patterson and Twiggs, encamped before the pass of Cerro Gordo.

Scott's plan of battle at Cerro Gordo was based upon the reconnaissances of the engineers. ''He had,'' says Wilcox, ''ordered an examination of the whole Mexican front, even around his left if practicable, to the Jalapa road, and upon reports made by Capt. R. E. Lee of explorations to that road, he based his orders of battle.''

In his final report of the operations including the Battle of Cerro Gordo, General Scott says:

> I am compelled to make special mention of Captain R. E. Lee, Engineer. This officer greatly distinguished himself at the Siege of Vera Cruz; was indefatigable during these operations in reconnaissances, as daring as laborious, and of the utmost value. Nor was he less conspicuous in planning batteries and in conducting columns from stations under the heavy fire of the enemy.

During Scott's halt at Puebla, the engineer officers were busily engaged exhausting all available sources of information of the Valley of Mexico. The advance to the City of Mexico was resumed on August 7, 1847. General Scott halted his leading division and established his headquarters at Ayotla. The engineers set out immediately to make a detailed examination of all available avenues of approach and of the surrounding country. Acting upon the information obtained by them, Scott on August 15th, began the movement to the south of the city via the southern shore of Lake Chalco. The American advance column reached San Augustin on the afternoon of the 17th and next day energetic reconnaissances were begun to discover the best route into the city. Lee and Beauregard, with an escort of two companies of infantry and Capt. Phil Kearny's company of dragoons, made an examination of the country toward Padierna. These two officers were able to bring back more en-

couraging reports than any of the other parties sent out. Scott determined on the strength of this information to move toward Padierna.

The engineer company commanded by Lieut. G. W. Smith, and of which George B. McClellan was a lieutenant, was reported to Lee for the construction of the road across the Pedregal. This job was rudely interrupted by the enemy's fire, which opened the first day's fight of the Battle of Padierna or Contreras.

On the night of August 19-20. Lee visited General Smith's headquarters to find out the exact state of affairs in this dangerously separated command. Of this incident, General Scott said:

> Captain Lee, of the engineers, came to me from Contreras with a message from Brigadier-General Smith. I think about the same time (midnight) he, having passed over the difficult ground by daylight, found it just possible to return on foot and alone to San Augustin in the dark, the greatest feat of physical and moral courage performed by any individual to my knowledge pending the campaign.

The Mexicans were badly beaten at Contreras on the morning of the 20th and fled precipitately toward Cherubusco and the City of Mexico.

In his report of the operations around the City of Mexico, the Commanding General said:

> At Chapultepec Captain Lee was constantly conspicuous, bearing important orders till he fainted from a wound and the loss of two nights sleep at the batteries.

Lee was successively brevetted Major, Lieutenant Colonel, and Colonel for his services in the Mexican Campaign.

When Mr. Custis, his father-in-law, grew anxious lest he be overlooked in the distribution of favors in Washington, Lee replied: "I hope my friends will give themselves no annoyance on my account, or any concern about the distribution of favors."

Towards the end of June, 1848, Lee was back at Arlington, nominally on temporary duty in the Office of the Chief Engineer but actually awaiting orders to take up once more the thread of peaceful pursuits. Orders finally came assigning him to duty in connection with the construction of the defenses of Baltimore, where he remained until 1852.

On September 1st of the latter year, he took up his new duties as Superintendent of the Military Academy; he remained at West Point until March 31, 1855. Lee was an ideal Superintendent, a

close observer of the cadets, many of whom were destined to serve either with or against him in mortal combat.

Capt. and Bvt. Col. Robert E. Lee of the Corps of Engineers, now 48 years of age, was appointed to and accepted the lieutenant-colonelcy of the newly organized Second Regiment of Cavalry, with rank from March 3, 1855. Says Gen. Fitzhugh Lee:

> Brevet-Colonel Lee left the Engineer Corps with great regret; he had thoroughly mastered its scientific details, and, with a national reputation, stood in the front rank of military engineers.

Albert Sidney Johnston was appointed colonel of the new regiment; William J. Hardee and George H. Thomas its majors.

Lee joined his regiment in the field at Fort Mason, Texas, from detached service, in March, 1856, and was assigned to the command of Camp Cooper on the Clear Fork of the Brazos. There now followed several years of hardship, spent mostly under canvas with detached service at various places, such as Forts Mason and Brown, Ringgold Barracks, Indianola, and San Antonio.

Colonel Johnston having been detailed in command of the Mormon Expedition, Lieutenant Colonel Lee in the summer of 1857 assumed command of the scattered regiment. He remained in Texas until the spring of 1861. Lee, while on leave, visited Arlington in 1858, following the death of Mr. Custis, and again in 1859 in connection with the administration of the estate. During his second leave, the John Brown raid occurred and he was selected as the commander to capture the agitator. He was promoted to Colonel First Cavalry, March 16, 1861.

When Lee arrived in Washington March 1, 1861, under summons from Texas, events were moving with great rapidity. The Cotton States had seceded, and in February established the Confederate States of America, with his old friend and fellow cadet, Jefferson Davis, as President. The hostility between the North and the South which had been "smouldering for years" had now "burst into bright flames."

To Lee was presented the most momentous question of his life: Should he stand by the old flag he had served for thirty-six years or follow the political convictions of his State? His struggle has been likened to that of the Savior in Gethsemane. He was being discussed at the time in Washington as the successor to General Scott. We may be sure of one fact: his decision was prompted by his sense of duty and honor. "Tell Custis," he wrote, "he must consult his own judgment, reason, and conscience as to the course

he may take. I do not wish him to be guided by my wishes or example.''

At last the great question was decided. In submitting his resignation to General Scott on April 20, 1861, he wrote:

> It would have been presented at once but for the struggle it has cost me to separate myself from a service to which I have devoted the best years of my life and all the ability I possessed.

Lee risked fame, fortune, and life itself, to fight for what he conscientiously conceived to be the right. No graduate of the Military Academy was ever truer to its present lofty motto: ''Duty, Honor, Country.'' ''Duty,'' he once remarked, ''is the sublimest word in the language.''

At the outbreak of the Civil War, as of the Mexican War, Lee seemed destined to obscurity. He was first appointed a major general of Virginia militia and, although ostensibly Military Adviser to Mr. Davis, he was in reality scarcely more than a ''recruiting and drill inspector'' in Richmond when, on July 21st his old engineer comrades, Beauregard and Johnston, were fighting the First Bull Run. On July 12th he had written to his wife, ''I am very anxious to get into the field, but am detained by matters beyond my control.''

Lee's first assignment to duty in this capacity was in command of the forces in Western Virginia. He accomplished nothing in a positive way, and was hailed by the press as a failure whose position had been secured through favoritism and the magic of an historical name.

Returning to Richmond, he was assigned to a duty supposedly more in keeping with his abilities, the supervision of proposed defensive work along the Carolina and Georgia coasts. As the fortifications progressed and the general situation became critical, General Lee was summoned to Richmond and on March 13, 1862, assigned as Military Adviser to the President. Things were going badly for the Confederacy: Forts Henry and Donelson had fallen in February; and McClellan's large and magnificently equipped army was being transferred to the Peninsula for a blow against Richmond. Lee was an ideal Chief of Staff, and gave sage counsel to Mr. Davis and Gen. Joseph E. Johnston in the latter's campaign to defeat McClellan and save the capital—in particular by approving and encouraging Jackson's Valley Campaign. It was with great regret that he saw the failure to destroy Keyes' Corps at Seven

Pines and the severe wounding of his classmate Johnston, even though the latter event gave him the opportunity of his life. It was to Lee that the Confederate President turned in this crisis. On June 1, 1862, Mr. Davis issued to Lee his short letter of instruction, in which he was directed to "assume command of the army in eastern Virginia and in North Carolina, and give such orders as may be needful and proper." The change of commanders did not meet with universal approval. The press had not forgotten the campaign in the western mountains. Lee was hailed as a swivel-chair warrior whose training as an engineer had rendered him too cautious for the bold offensive that the occasion demanded. Even some of the senior commanders, who had justly learned to revere Johnston, were full of misgivings. Longstreet afterwards stated that the appointment fell far short of "reconciling the troops to the loss of their beloved Chief, General Joseph E. Johnston, on whom all hearts leaned and whom all loved. . . . his (Lee's) West Virginia Campaign . . . was not successful." As an engineer Lee had been "especially distinguished" but, said he, "officers of the line are not apt to look to the staff in choosing leaders of soldiers, either in tactics or strategy," a criticism which obviously applied to Johnston as well. Camp gossip was busy speculating as to whether the new leader possessed the audacity and genius of a great captain.

Lee was now 55 years old, in perfect physical condition, ripe in experience, and in the full zenith of his great intellectual powers. He was destined to deliver blows that for boldness startled even the most reckless. He needed no German text-books to teach him that only by the assumption of a vigorous offensive could the Confederacy hope to establish itself.

Lee assumed command of the army before Richmond, numbering some 57,000, on June 1st, with the following situation confronting him: In his immediate front stood the Army of the Potomac, 95,000 strong, unshaken by the Battle of Seven Pines. In the Shenandoah Valley, Stonewall Jackson, encumbered with a 7-mile wagon train and long column of prisoners, the booty of his successful campaign against Banks, was slowly making his way toward Staunton, attempting to shake himself free from Frémont and Shields, in dogged pursuit. The latter, with his own and Ord's Divisions, had been detached from McDowell at Fredericksburg, over his protest, leaving only McCall's Division of 10,000 available

to reinforce McClellan, whom they joined on the 12th and 13th, instead of the entire Corps of 40,000 as originally intended.

Lee spent the first few days of June in readjusting and strengthening his lines, weighing the information at hand, and reaching his decision as to the offensive campaign to be undertaken. He early conceived the idea of repeating the strategy of First Bull Run. Jackson was to be reinforced, ostensibly for a new campaign in the Valley. He was then to move down and join hands with Longstreet, A. P. Hill and D. H. Hill. Their combined forces were then to overwhelm Porter's isolated Corps of 30,000 forming the Federal right, seize the railway to White House, and drive McClellan's entire panic-stricken army into the swamps of the lower Chicahominy.

McClellan had available about 105,000 men; Lee, with Carolina and Georgia reinforcements and Jackson's troops, about 83,500.

All critics agree that Lee's plan of campaign was magnificently conceived and practically all agree that it went awry through little fault of his own.

The first untoward incident was Stuart's spectacular raid around the Union Army, June 11-15. This was a daring exploit but it did the Confederates ultimate harm, since it set McClellan to thinking about his communications and the desirability of having an alternate base on the James.

One of the greatest enigmas of the Civil War is Jackson's conduct in the Seven Days Campaign. When summoned to Richmond for conference to perfect the plans, and in anticipation of the early issuance of an order for battle, Jackson was on his secret movement from the Valley. His troops had had several days rest before starting and his infantry were being assisted by rail. Jackson himself set June 25 as the day for his blow against Porter; but Longstreet, to make assurance doubly sure, suggested the 26th, which was agreed upon. Jackson did not start on the 26th at the hour nor from the position explicitly ordered by Lee. He arrived within striking distance of Porter about 4.30 p. m., instead of in the forenoon, and then made no effort to march to the assistance of his prematurely embattled comrades.

A. P. Hill, instead of awaiting Jackson's arrival on the 26th, as ordered. grew impatient and finally made a frontal attack upon Porter in position at Beaver Dam. He not only flushed the quarry, but in so doing met a "bloody and disastrous repulse."

There was time enough on the 27th to repair in part the blunders

of the 26th; but Jackson failed at Powhite Creek, as he did later at Savage Station and Frasers Farm.

As a result of the Seven Days Campaign, Lee's newspaper critics were confounded; the entire South hailed him as the genius destined to deliver them and their soil from the foeman. The Army of the Potomac from the offensive was forced to the defensive; the besieger became the besieged; and its commander but for rapidly moving events even now would have been deposed. To the Southern leaders, however, the campaign had been one of lost opportunities.

At the beginning of the Seven Days Campaign, the Armies of McDowell, Banks, and Fremont were consolidated into the Army of Virginia, under Maj. Gen. John Pope, and concentrated around Sperryville, Little Washington and Warrenton, with King's Division detached at Falmouth. This command numbered about 47,000. McClellan had about 90,000 fit for duty at Harrisons Landing, and Lee stood between the two armies at Richmond with some 55,000.

Lee was very anxious that McClellan be recalled or not reinforced. He revolved in his mind plans for utilizing his interior position to strike Pope before he could be reinforced by McClellan. About July 13, convinced that McClellan's fangs were drawn, he ordered Jackson to Gordonsville to observe Pope.

There now followed Jackson's battle against Banks at Cedar Mountain; the concentration of Pope's and Lee's armies first on the Rapidan, then on the Rappahannock; and the gradual withdrawal of McClellan, whose leading corps were already rapidly marching to effect a junction with Pope.

On Lee's part the Second Bull Run Campaign was "an illustration of the daring, not to say hazardous, policy which he pursued in this summer of 1862" (Ropes). General Lee remarked that "the disparity of force between the contending forces rendered the risks unavoidable."

In war, nothing succeeds like success. To the victor everything is forgiven. Pope was completely demoralized during the succeeding movements of Lee and Jackson, August 25 to September 1. He had announced his "headquarters in the saddle," where indeed they were at this period, until he established them more permanently in a bomb-proof within the defenses of Washington.

Of Lee's movements up to this time, General Alexander remarks:

At the beginning, the enemy had been within six miles of Richmond. He was now driven within the fortifications of Washington, with a loss in the two campaigns of about 33,000 men, 82 guns, and 58,000 small arms: Lee's own losses had been about 31,000 men and 2 guns. The critics who had declared he would never fight were forever silenced and pilloried in shame.

In the Battle of Chantilly, the Union Army had suffered the loss of Generals Kearny and Stevens. The latter, an old engineer comrade of Lee's in Mexico, it is said, was slated for the command of the Federal Army.

To gain some idea of the panic in Washington during the Campaign of Second Bull Run, one has only to read the official dispatches. Lee, flushed with victory and thoroughly imbued with the spirit of the offensive, now proposed to President Davis that advantage be taken of this demoralization to carry the campaign beyond the Potomac, although he realized his army was "not properly equipped for an invasion of an enemy's territory." To stand still would be to risk everything gained in the previous operations.

The political and military leaders thought that the presence of a Southern Army on Maryland soil would bring many recruits into its ranks, relieve the pressure on Virginia and perhaps western points and, if a great victory could be gained, probably end the war.

Lee purposely crossed the Potomac to the east of the Blue Ridge and concentrated his army at Frederick. Here he issued a proclamation to the people of Maryland, and on the 9th of September his now famous "Special Orders, No. 191," which scattered his divisions to the four winds. On the morning of September 13, a copy of this order was found in an abandoned Confederate camp and promptly turned over to McClellan, advancing cautiously from Washington. Lee was informed of this mishap by Stuart the same night. The succeeding movements, culminating in the Battles of South Mountain, Cramptons Gap, and Antietam, afford excellent keys to the respective abilities of the Confederate and Union commanders. Lee extricated himself promptly and with consummate finesse, while McClellan's management of his great opportunity was "halting, dilatory, wanting in firm direction and to a degree irresolute and unskillful."

Lee was unwilling for the moral effect to recross into Virginia without offering battle. Antietam, or Sharpsburg, generally called a draw, was one of the bloodiest contests of the entire war. Lee

has been criticised for his position with a large river at his back but under the circumstances, being determined to fight, it was about his only choice. The Confederate Army moved to the south bank of the river on the night of September 18-19, and the Maryland Campaign was at an end. McClellan was so slow in his pursuit that he was finally relieved of command, his not too confident successor being Gen. Ambrose E. Burnside.

Burnside proposed to move his army to the Rappahannock, seize Fredericksburg, and advance by the railway leading thence to Richmond. His plan was approved by President Lincoln.

Of interest to engineers is the incident of the delayed pontons, to which Burnside attributed the inauspicious start if not the failure of his campaign. Before the means of crossing the river had arrived he found General Lee occupying the height south of Fredericksburg, on the strategical and tactical defensive.

''The Battle of Fredericksburg,'' says Gen. Fitzhugh Lee, ''was a farce which one could laugh at, except for the sacrifice of human life. A grand army seeks offensive battle, makes isolated attacks by fractional forces, remains in position two days, and secretly in the midst of a violent storm recrosses the river during the night, with a loss of twelve thousand six hundred and fifty men.''

The useless slaughter at Fredericksburg was a terrible blow to Mr. Lincoln. The telegraph brought first the news that the army had ''withdrawn'' to the north bank of the Rappahannock. Afterwards the horrible details arrived with lists of the dead.

The winter of 1862-1863 was a dark period for the Union. The events connected with the deposition of Burnside and the elevation of Hooker were perhaps the most dramatic of the entire war. Mr. Lincoln wrote Halleck, ''If in such a difficulty as this you do not help, you fail me precisely in the point for which I sought your assistance.'' Fredericksburg took the spirit out of the Army of the Potomac. The soldiers were beginning to feel that the North had no leaders who could cope with Lee and Jackson, and that their blood was being shed in vain. Brother officers were arrayed against each other in factional strife; and the soldiers rightly considered themselves the victims.

Burnside's ultimatum that either he or Hooker go was promptly acted upon by the President. Lincoln's letter to the latter is justly considered one of the most remarkable documents in history. It

was full of sound advice and prophetic forebodings. Its fulfillment was Chancellorsville.

The new Federal commander availed himself of the period following Fredericksburg to reorganize the Army and restore its confidence. In this he was quite successful, though the senior officers had their misgivings. As the season of active operations approached, both Lee and Hooker drew up plans to resume the offensive. The Army of the Potomac, recently reviewed by the Commander in Chief, moved first with all the advantage of numbers and initiative.

With Longstreet absent, the Confederates numbered about 60,000 with 170 guns, the Federals about 134,000 with 400 guns. Hooker enthusiastically spoke of his army as the "finest on the planet" and boasted that he intended to march "straight to Richmond." His army was possessed of all that the soldiers could wish for. On the other hand, the Southerners were half naked and had seen the detachment of a considerable number of their brethren through sheer hunger.

Hooker's plan of campaign has been pronounced excellent and its execution masterly up to the point of actual collision. Here he hesitated and was lost. "With energy and sleepless vigilance" he had forged his tool and set it in motion, but had stopped it at the crucial moment. Was he drunk? Was Mr. Lincoln's caution, "Beware of rashness," ringing in his ears? It were useless to enter upon that controversy. "Fighting Joe" lives in history as a great corps commander but unequal to independent command. It is rather anomalous that in his one great campaign his strategy should have been faultless but his tactics miserable.

Chancellorsville has been pronounced by many Lee's greatest victory. The news from the Rappahannock dumbfounded Mr. Lincoln and the North. "Fighting Joe" had been weighed in the balance and found wanting.

General Lee had been in command of the Confederate Army about eleven months. In this brief period he had fought, with vastly inferior numbers and resources, five campaigns, one of which he had carried into the enemy's country. On the pages of history had been written Mechanicsville, Gaines Mill, Savage Station, Frasers Farm, Malvern Hill, Antietam, Fredericksburg, and Chancellorsville. He had unhorsed McClellan, Pope, Burnside, and Hooker, and was as yet a stranger to defeat.

What can be said of the Gettysburg Campaign that would not

be "a twice told tale"? The Army of Northern Virginia had reached the point where it considered itself invincible in battle. Great neutrals in Europe were becoming restless under trade restrictions. The "Copperheads" in the North were asking for peace. The Southern Army looked with longing eyes to the rich sources of supply in Maryland and Pennsylvania. Lee was anxious for one more attempt north of the Potomac which might atone for his previous accidental failure; by carrying the war onto Northern soil the pressure on Chattanooga and Vicksburg might be relieved. Lee realized that a waiting game would mean his destruction. A desperate cause requires desperate chances.

The Southern leader crossed the Potomac for the second time in June, 1863, and displayed the "Bonny Blue Flag" as far north as Carlisle, York and Harrisburg; offered offensive battle for three days at Gettysburg, and then withdrew intact into Virginia.

The campaign was a political and military failure. It is useless to speculate on what might have been had Jackson been alive, had Stuart not gone astray, and had Longstreet been a little more eager to help his chief. Lee entered upon the campaign with some 76,000 men and 272 guns; Hooker with about 115,000 men and 362 guns. The Federal and Confederate losses were 20,000 and 28,000, respectively.

Upon Lee's great opponent, Meade, had been thrown a heavy task. Although it had been decided after Chancellorsville never to allow Hooker another opportunity to fight, still he was kept in command until June 27. Gettysburg and Vicksburg, twin disasters, marked the beginning of the end for the Confederacy. Thereafter it tottered to its inevitable fall.

When the campaign opened in the spring of 1864, Lee faced his last and greatest opponent. The victor of the East was pitted against the victor of the West. The Army of Northern Virginia stood facing the Army of the Potomac across the Rapidan. Their respective numbers were 62,000 and 105,000. Grant took the initiative; on May 4th he crossed the river in an attempt to turn Lee's right and interpose between the Confederate Army and Richmond. As the Federal columns were marching through the jungle near the old battlefield of Chancellorsville on May 5th, Lee struck them and brought on the terrible Battle of the Wilderness. Grant shook himself loose and continued the movement by the Southern right, only to find his great opponent across his path at Spottsyl-

vania Courthouse, where the second bloody contest of the campaign occurred.

The Federals continued the movement to the southeast, once more finding Lee in line of battle across their front; first behind the North Anna and then behind Totopotomy. These positions were so strong that Grant refused battle; but his patience was exhausted when Lee once again blocked his way at Cold Harbor. Here in the neighborhood of Malvern Hill, Grant launched a great assault which Lee repulsed as easily as McClellan had done his own in 1862. The Federals lost 6,000 men in about an hour. On the night of June 12th, Grant began his movement to the south bank of the James. His losses in the brief campaign had been 55,000, or almost equal to Lee's command at the outset. He had arrived finally where he had been urged to land by water transportation. The tedious siege of Petersburg was now inaugurated. The lion, bleeding from wounds inflicted by many successive antagonists and lean with hunger, was at bay. Appomattox was in sight.

It is a matter of keen regret to Southerners, who have the sporting instinct of their English forebears, that Grant and Lee did not meet when their resources in men and material were more nearly equal. The Southern people believed that their great leader had accomplished all that mortal could, and when he surrendered they were willing to acknowledge themselves beaten.

General Lee was by nature dowered with that indefinable thing called military genius. He was also a close student of the great campaigns of history. Quick in grasping a situation, prompt in decision, careful in planning, bold in execution, he has taken his place among the great captains of history.

Unfortunately, he wrote no memoirs; he left his deeds to justify themselves. A striking feature of his character was his great moral courage; he was the captain of his soul. He accepted all the responsibility for disaster. Hence there was among the Southern leaders of that petty bickering so common among the Federal leaders less of that petty bickering so common among the Federal his being a party to the treatment accorded those great corps commanders, Fitz John Porter and G. K. Warren.

His noble nature led him into his greatest defect, a proneness to overlook mistakes in his higher subordinates. When Stuart reported at Gettysburg, his only comment was: "Well, General, you have arrived at last." The South fought the war with the same

generals, whereas change was the natural order in the North. This had its bad as well as its good features. General Lee's character was free from even the smallest vice. To the South he is the ideal of noble manhood. When from Appomattox the news of Lee's surrender reached the prostrate Southern people there must have occurred to them those beautiful lines of the great poet:

> How like a deer, stricken by many princes,
> Dost thou here lie.

Grant and Lee, and their fellow graduates North and South, have added undying fame to their Alma Mater at West Point. They have done more; they have increased the prestige, not only of their own land, but of the Anglo-Saxon race.

In the fulness of time, after passion had died out, the love of a great people bore the body of the Great Napoleon from St. Helena to the banks of the Seine and placed it in a sarcophagus "fit almost for a Deity dead." What spot so appropriate for the last resting place of Robert E. Lee as his own beloved Arlington on the banks of the Potomac, the most beautiful and hallowed field of sepulture on the face of the globe!

The Sidehaul Railway Dry Dock at West Memphis, Arkansas.

BY

Maj. CLARKE S. SMITH,
Corps of Engineers.

The United States operates a plant consisting of dredges, tenders, quarterboats, derrick boats, etc., for the purpose of maintaining a navigable channel in the Mississippi River below Cairo during low water, for making surveys, and for other work. The plant, being quite extensive, requires an almost continual service in making repairs and improvements to some particular item of the various units. Very frequently such work can only be done when the vessels are on a dry dock, and it was with the object of having such a structure always available that the side-haul railroad dry dock opposite Memphis, Tenn., was constructed.

This dry dock has a capacity sufficient to carry a vessel weighing 1,500 tons. The largest dredge now in use is the *B. M. Harrod,* weighing 1,270 tons; and consequently the dry dock is able to lift this weight. The length of the *Harrod* is 210 feet and the beam 47 feet, dimensions which can be accommodated.

In locating the dry dock it was necessary to select a stable bank; that is, one not having any tendency to cave either at present or in future, if indeed the condition as to future caving could be foreseen. Sufficient depth of channel was required for boats to have access to the dock, particularly at low river stages, as well as enough depth of water in front of the dock for operating the latter during the low water period; a location where there was liable to be a large deposit of sediment or a bar formed was therefore to be avoided. While a little trouble has been caused by sediment at the outer edge of the dock, the selected location at West Memphis seems generally to have met these requirements in a satisfactory manner.

The dock is of the side-haul railway type adapted for use, except at extreme high water stages, in a river where the surface fluctuation has been 49.2[1] feet and may be expected to be 30 feet

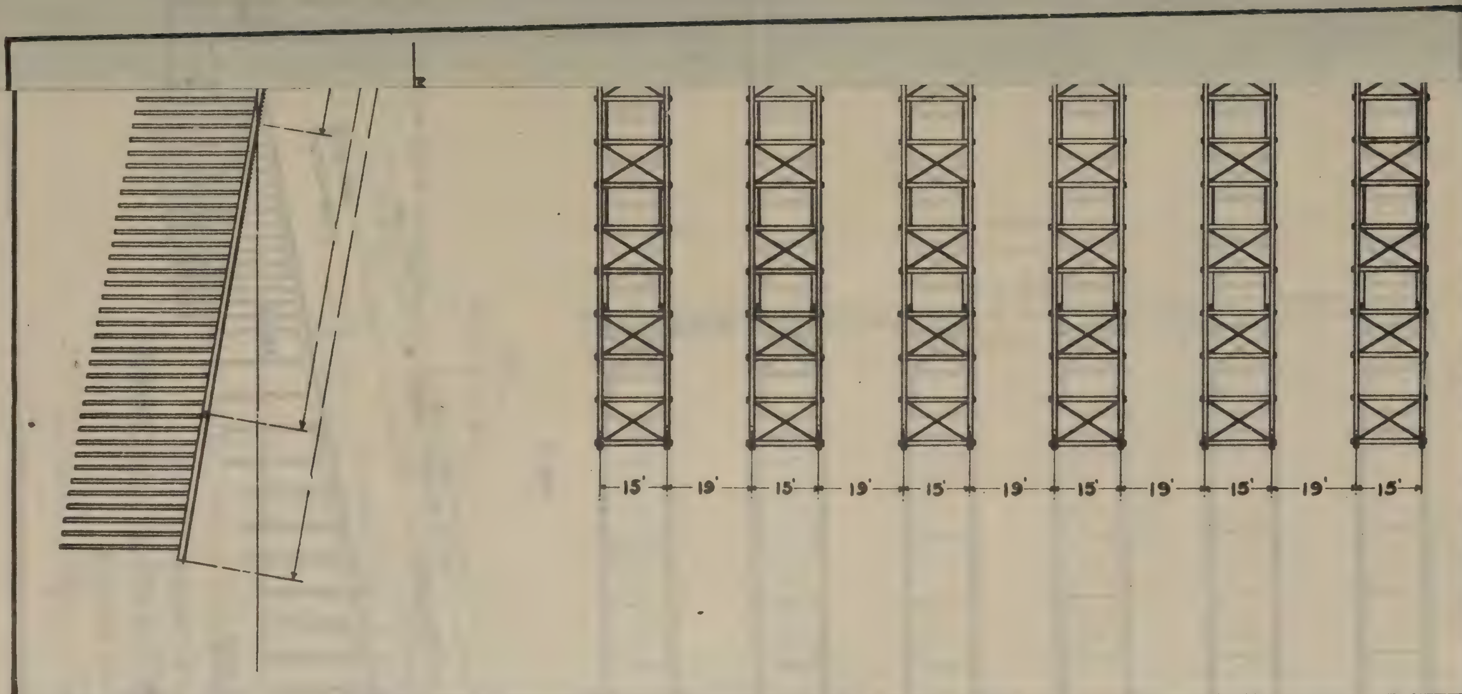
[1]Highest, 46.55 feet (Memphis gage), April 9, 1913;
Lowest, —2.65 feet (Memphis gage), November 6-9, 1895.

or more annually. There are six steel cradles (Fig. 1), which operate on inclined tracks, the motive power being a steam engine at the top of the bank, which transmits its power to the cradles by means of suitable gearing, shafts, and chains.

The tracks are steel rails of the usual railroad type, resting on beams inclined at an angle whose tangent is 1 vertical and 6 horizontal and in turn supported by piling. These beams are reinforced concrete above the 10-foot river gage and creosoted yellow pine between the 10 foot and 0 foot of the gage; below that level they are uncreosoted pine. (Fig. 2) Likewise, the piling supporting the concrete beams are of reinforced concrete, those supporting the creosoted timber beams are of creosoted pine and those supporting the uncreosoted beams are untreated pine. The cradles are six in number, and are spaced 34 feet on centers. The distance between the centers of the outside tracks of the dock is 185 feet. Each cradle is independent of the others and is composed of two triangular frames suitably united by steel ties and braces. (Fig. 3.) To the lower member of each frame is attached twenty-three wheel trucks, each carrying a chilled iron double flanged wheel, 12 inches in diameter, to give easy motion to the cradle over the tracks. The top member of each cradle, when the latter is drawn up to its highest position, is 38 feet above 0 of the Memphis gage, and when lowered to its lowest position is 5 feet below 0 of the same reference. A cradle is moved by two hauling chains, each of which is made up of two sections; one of the long link type attached near the upper end of each lower member of each frame travels along the rail around a chain wheel at the top of the bank, and another of the close link type, attached to the upper end of each frame, travels along the rail around a sheave at its lower end and thence up to its junction with the long link chain.

The chain wheels at the top of the bank are operated by six winches (Fig. 4), one to each cradle. One chain wheel is attached to each end of a shaft, at the middle of which is a wheel about 6 feet in diameter moved by a worm gear, the latter being connected by bevel gears to the line shaft which operates all the winches, the line shaft receiving its motion from the engine. The bevel gear on the line shaft can be thrown in or out of gear, thus making it possible to move as many of the cradles as desired and leave the remainder at rest.

The line shaft which operates the six winches is rotated by two horizontal engines situated at the middle point of the shaft. Either


15'
19'
15'
19'
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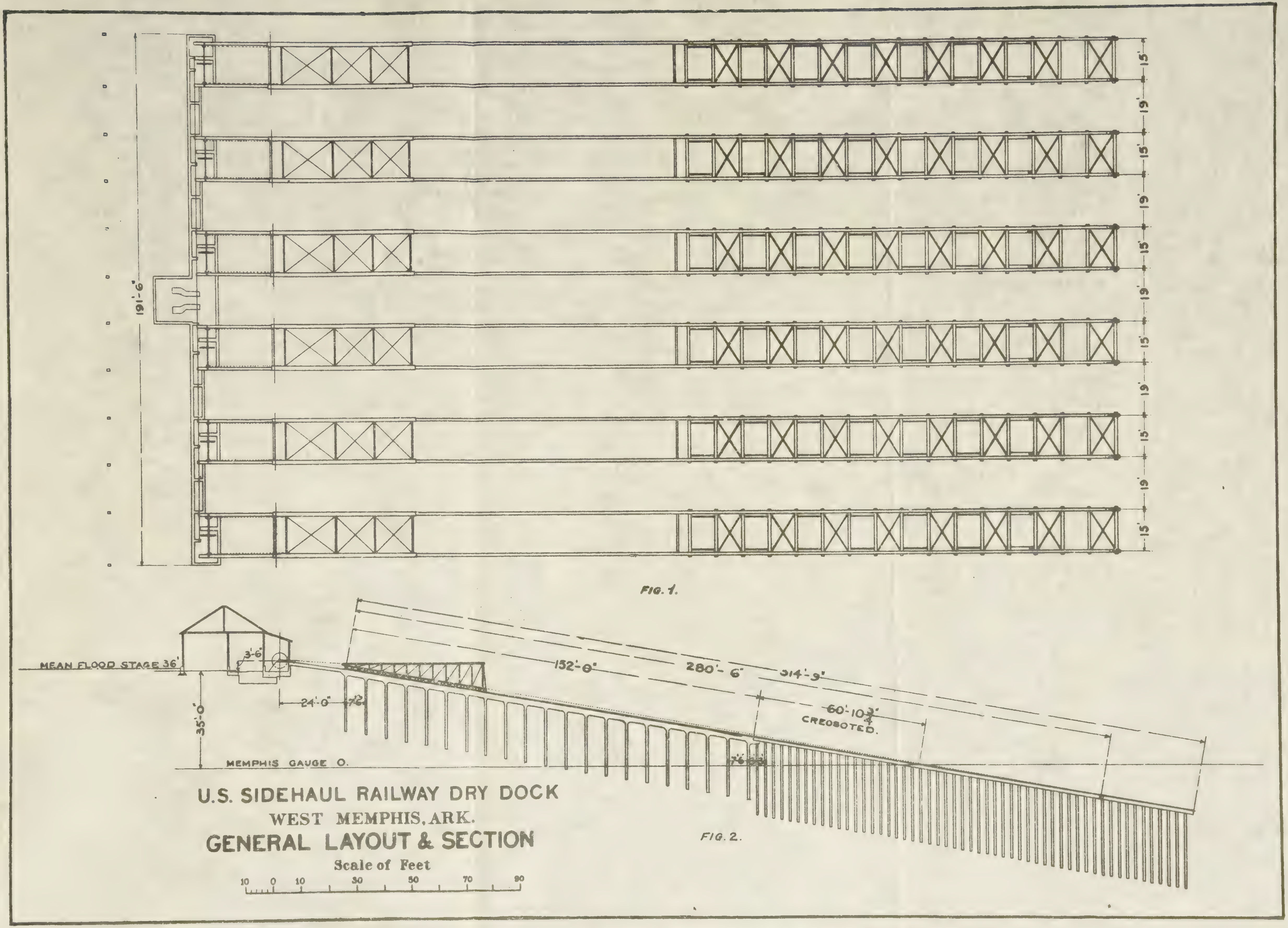
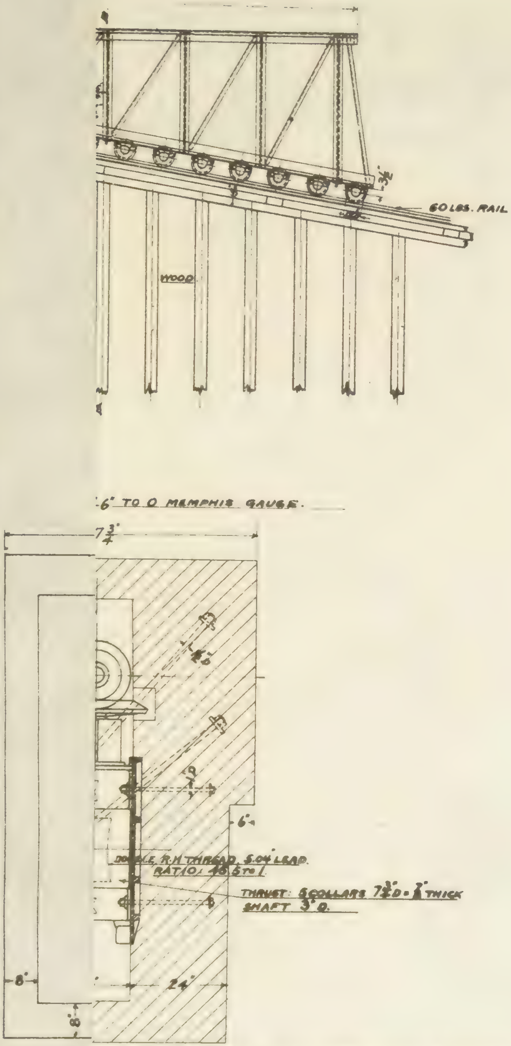
15'


191'-6"
15'
19'
FIG. 1.
MEAN FLOOD STAGE 36'
3'-6"
24'-0"
35'-0"
MEMPHIS GAUGE 0.
132'-0"
280'-6"
314'-9"
60'-10 3/4"
CREOSOTED.
FIG. 2.
U.S. SIDEHAUL RAILWAY DRY DOCK
WEST MEMPHIS, ARK.
GENERAL LAYOUT & SECTION
Scale of Feet
10 0 10 30 50 70 90

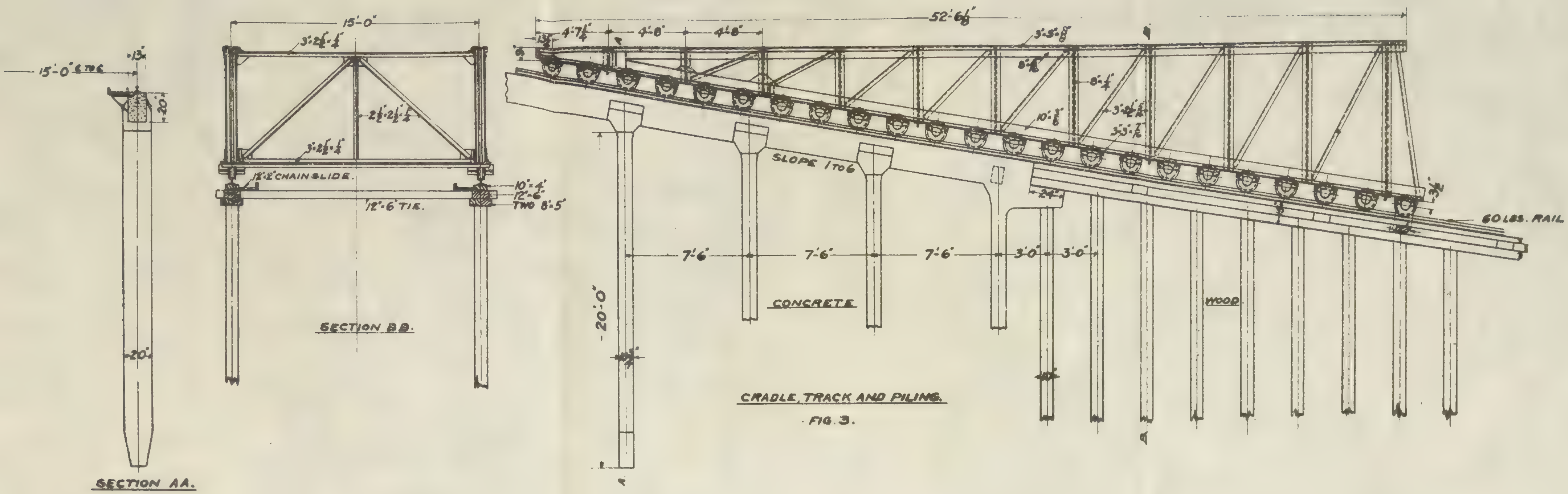


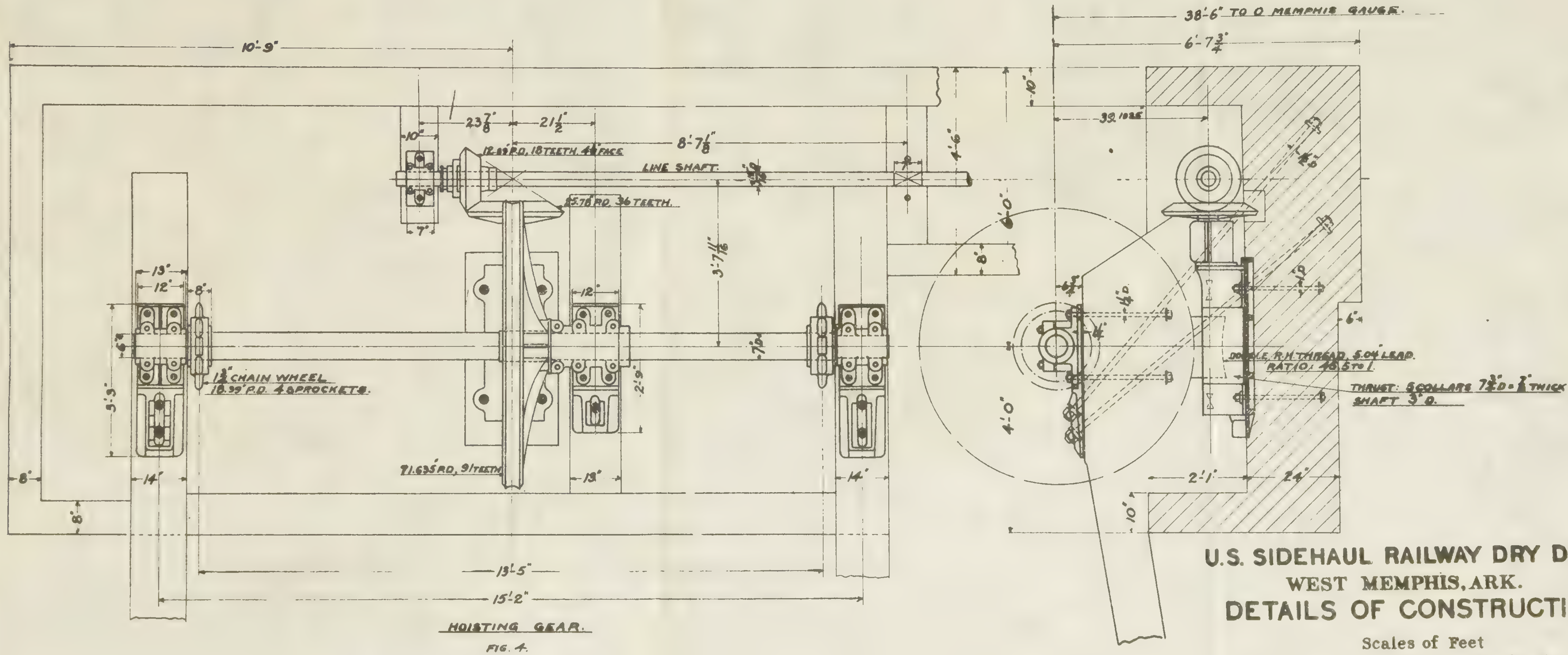
U.S. SIDEHAUL RAILWAY DRY DOCK

WEST MEMPHIS, ARK.

DETAILS OF CONSTRUCTION

Scales of Feet





U.S. SIDEHAUL RAILWAY DRY DOCK

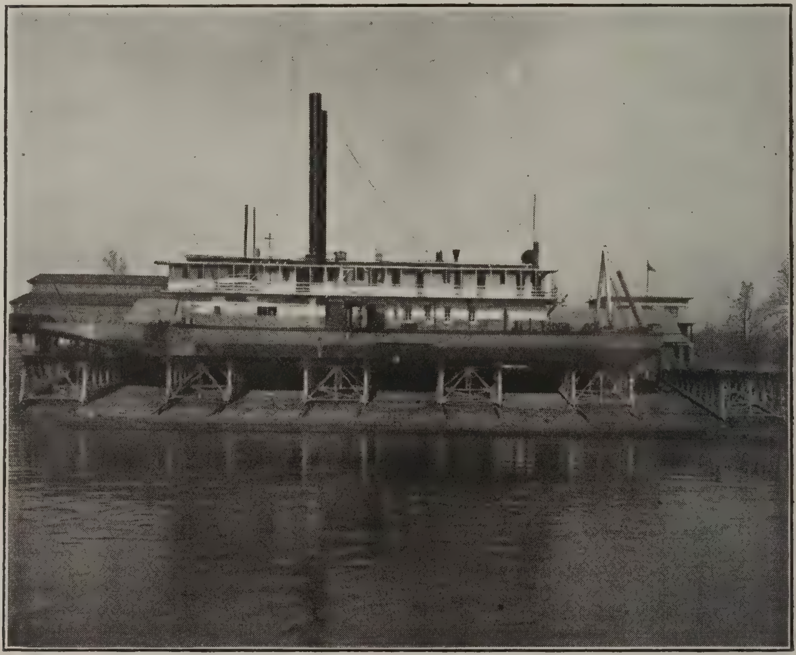
WEST MEMPHIS, ARK.

DETAILS OF CONSTRUCTION

Scales of Feet

of two sets of spur gears, as desired, transmits the power of the engine to the line shaft and a fast or slow motion may thus be given the movement of the cradles, the former to be used for empty or lightly loaded cradles and the latter for heavy loads. This gearing gives the cradles a motion of either 7 or 4 feet per minute.

The engine and machinery rest on concrete and are protected from the weather by a suitable house. The bearing power of the ground for the concrete machinery supports was taken at 1,000 pounds per square foot. As a result of this low figure, no notice-

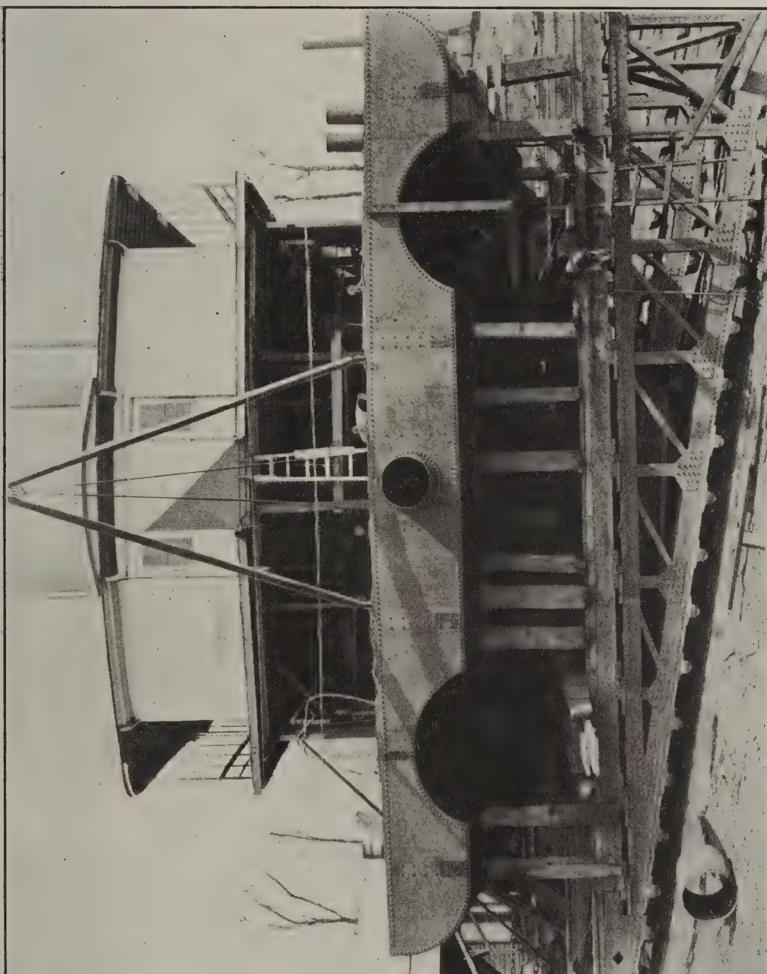


able settlement has occurred and no difficulty has been had with the alignment of the line shaft which operates the winches.

The usual time required to dock or undock heavy boats is 45 minutes. The upper surface of the cradles may be aligned before docking a boat by placing them in the water with the top members just awash.

A device was provided on top of each frame of the cradles to allow an individual cradle to be released without disturbing other cradles which are carrying a load, but not much advantage was thus obtained and it is no longer used.

One improvement would have been to have had one additional



bevel gear wheel at each winch, so that some of the cradles could have been lowered while others were being raised.

In constructing the dock the concrete piling were jetted down; the track and timber beams for the track below 10 feet on the gage were assembled in their relative positions and suitably braced together; then were floated to their positions over their piling supports and sunk to their places on the piles and spiked thereto, the tops of the piling having been sawed off at the proper elevations.

Other details of construction are as follows:

The rails are of railroad section, 60 pounds per yard; steel for cradles, consisting of angles, plates and columns, is open hearth medium grade having an ultimate tensile strength of 60,000 to 70,000 pounds per square inch, the percentage of elongation in 8-inch test pieces being not less than 22 per cent, reductions of area not less than 40 per cent, and elastic limit not less than one-half of the ultimate strength. The long link hauling chains have a breaking strength of not less than 155,000 pounds each and are proof tested to 70,000 pounds each, while the corresponding figures for the close link chains are 30,000 and 14,000 pounds. The shafts are of steel, accurately machined, while the gears are iron, accurate in pitch and diameter, and the winch worms hard bronze. The concrete used for the machinery foundations was made up of one part Portland cement, two and one-half parts of clean sand and five parts of broken stone, all measured by bulk.

The dock was constructed by contract and cost $95,120. The buildings used for protecting machinery and for a work yard cost about $2,400 additional.

Data as to tonnage handled, number of dockings, cost of operation, etc., are given below, the figures representing an average per year for the past three years:

Tonnage handled .... tons..	4,336
Number of dockings	20
Average load .... tons..	282
Maximum load handled .... do...	1,233
Cost of operation per year	$385.00
Cost of repairs per year	833.00
Cost of operation, per ton	.09
Cost of operation per ton, including repairs	.29

The saving due to having this dock available is apparent and has been large; there is no other dock suitable for the purpose required within a distance of 200 miles by river, either up or down stream, and it has been indispensable to the work for which it is operated.

Repointing Sea Wall at Governors Island, N. Y., with Cement Gun.

BY

Mr. HENRY N. BABCOCK,
U. S. Assistant Engineer; M. Am. Soc. C. E.

With about $3,000 remaining from an appropriation for repair of the sea-wall at Governors Island, it was decided to repoint the west side of the sea-wall. This sea-wall is built of heavy stones laid in courses; none of the courses required to be of uniform height throughout except the coping, which was 1 foot high and 3 feet wide. The joints were ordinarily 1 to 1½ inches thick, sometimes reaching 2 inches. On the northwest, or Hudson River, side of the wall the mortar had come out of the joints, almost generally, indicating that the joints had not been made full, but voids had been left in which ice formed.

Frequently the joints were found open to a depth of 2 feet or more. It would be impracticable to fill them completely by the ordinary method of repointing, under which the mortar seldom, if ever, is pushed in 6 inches from the wall face. Therefore it was decided to try the "Cement Gun" on this work, a novel use for this tool, the makers having no knowledge of its having been used for repointing.

The Cement Gun is a machine for receiving a mixture of cement and sand, distributing it through a very large volume of air under high pressure, which carries it through a hose. At the nozzle it is mixed with water in a fine spray, also delivered under pressure, and the wetted material is discharged with considerable force.

The machine gun consists of two hoppers, each holding about 2 cubic feet of sand and cement (in the size of machine used), one hopper above the other and each closed by a cone-valve opening upward. The upper hopper is filled with sand and cement, mixed; then the upper cone is closed and the lower one opened in order to feed the lower hopper, which is under air pressure. A screw at the bottom of the lower hopper regulates the feed into the sand hose; the screw is operated by compressed air. The length of sand hose which can be used conveniently is about 50 feet.

With the cement gun, an air pressure is required capable of delivering about 100 cubic feet of air per minute at pressure of about 60 pounds at the compressor (which would reduce to about half as much at the nozzle), and a force pump to deliver about 5 gallons of water a minute under 45 pounds pressure. These figures are by no means exact. Apparently the compressor would answer for

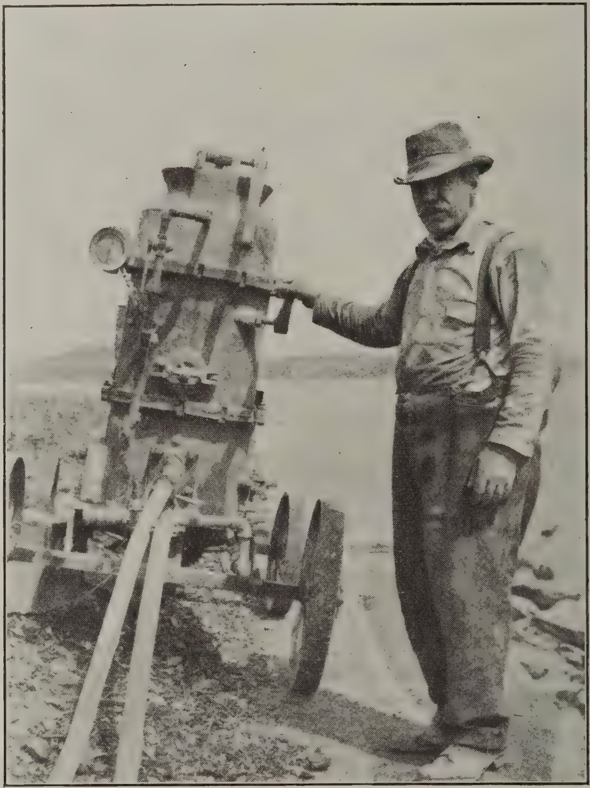


Fig. 1. Cement Gun.

service with 33 per cent variation either way, and the force pump with 50 per cent variation.

The compressor was procured by the Cement Gun Co., and leased to the work by them. It was a large machine, much larger than required, and was driven by a gasoline motor which used 3 gallons of gasoline for one hour's work. The pump was furnished by the United States. It was a small Gould's "Pyramid" pump, with a rated capacity of 6 gallons of water per minute at 50 pounds

pressure. It was mounted on a side platform of the compressor and driven by a belt from a pulley on the fly-wheel shaft.

The Cement Gun Company furnished the cement gun at $250 a month; the air compressor at $5 a day; an operator for the gun at $6 a day, and an engineman to run the compressor at $4 a day. The United States furnished 5 to 7 laborers, a horse and cart and an overseer. The lease with the Cement Gun Company also provided for payment to them of transportation charges on the plant and for 4 days' time allowed for transportation. The transportation charges were $216, being about trebled for the requirement of delivery on the island.

Fig. 2. Cement Gun.

Work was begun at the north end of the extension sea-wall near Castle William on June 1, 1916, and was stopped June 29, 1916, at a point 4,170 feet from the beginning. The linear feet of joints pointed was about 22,320, averaging 900 feet to the working day. At the beginning, the rate was much slower on account of inexperience and bad weather, although the location was near the sand pile and the cement storage. The rate also varied on account of tides, more work being accomplished when low tides occurred near the middle of the day.

In filling the joint, the operator turned on water only until the

joint was washed clean, then the mixture of cement and sand with the water, sweeping over any convenient length of 4 to 8 feet at a time. The mortar filled the joint gradually in from 2 to 5 minutes depending largely on the voids as well as on the length covered. When the joint was nearly full, the visible completion appeared sudden.

The operator stood on the riprap foundation of the wall during work until the tide rose too high for rubber boots, when a plank swing was hung over the wall for a platform; this was for about 33 per cent of the time.

Some difficulty was met with in the lower joints, which are under water at high tide. They could be filled only at low tide, and the swash of waves or swells from passing steamers would often wash

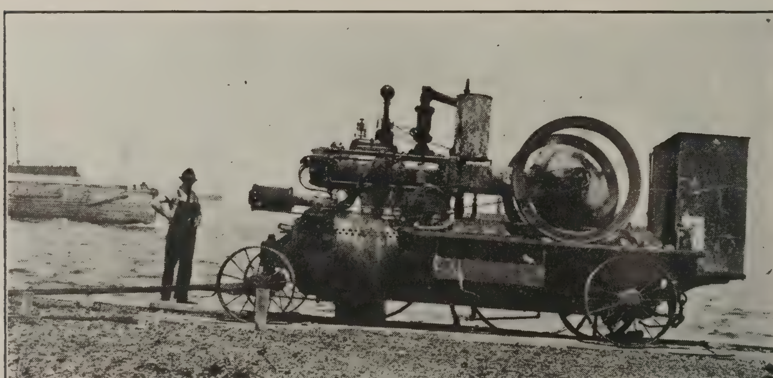


Fig. 3. Compressor and Pump.

out the mortar for a depth of 3 to 6 inches, a result which would happen from any pointing. Covering these joints with a weighted canvas screen was tried, but it was not effectual. Towards the close of the work, a few linear feet of joint were covered with plaster of Paris, $\frac{1}{8}$ to $\frac{1}{4}$ inch thick. This set at once and stayed on for a day, when the cement had hardened. It was rather slow and expensive for general use.

At the beginning of work, the belt drive from the compressor to the pump wore out and broke frequently. The operator often had to shut off the water, which stopped the pump while the compressor was running. A relief valve in the water line remedied this.

This kind of work unavoidably makes a joint without finish

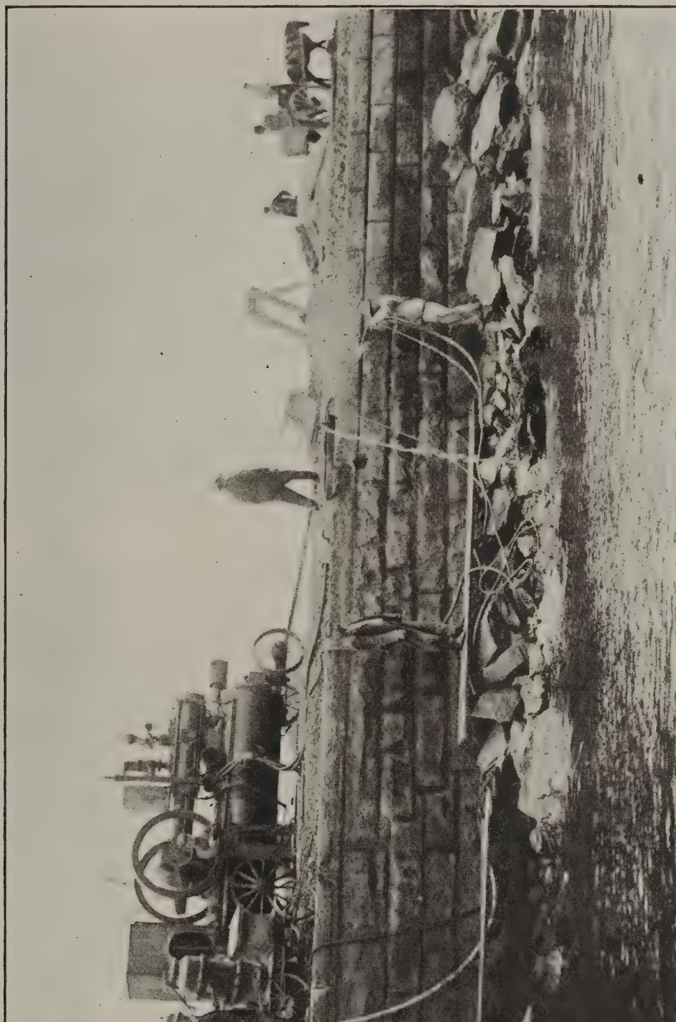


Fig. 4. Cement Gun at Work.

and spatters mortar on the face of the wall. One of the laborers was assigned to smoothing off the joint and cleaning away the surplus mortar before it had set.

It was at first intended to mix the cement and sand at 1 to 2. The Cement Gun men said that their experience led them to believe that the force with which the mortar was driven caused some of the sand to rebound, and that 1 to 3 was a better proportion. This was adopted. In these closed joints, however, the loss of sand from this cause was small. It is estimated that between 10 and 15 per cent of the mortar was wasted from spattering and overfilling the joints, and that this contained practically the same proportion of sand as the original mixture.

To drive the cement and sand through the hose with compressed air, it is essential that the mixture be quite dry. In the early part of June there was much damp, foggy weather and the sand got damp and, although the cement was kept quite dry, the mixture clogged in the hose. It is very probable that the compressed air was also fully saturated. The trouble was overcome by heating the sand on an iron plate over a fire of drift wood.

The filled joints were probed with an iron bar at several points to see whether the mortar penetrated the full depth of the joint. It appeared to do so. A test was made by building a box 3 feet long (the maximum depth of joint), 18 inches wide and 1 inch high, with one end, 18 inches by 1 inch, open. This was laid flat on the wall and mortar driven into it with the gun, as in ordinary work. The box was covered with canvas and sand, and after three days it was opened. The mortar had filled the entire box, with exception of a small pocket of dry sand on each side about half way in, and another very small one at each back corner. The slab of mortar was cracked through in two places, during handling. The bottom of the slab was homogeneous and smooth, with impression of the grain of the wood. The top was uniform only for the outer 12 inches; farther back it had several depressions of ⅛ inch or less, looking as if water had stood there, separating from a too wet mixture, and had dried away. The character of the mortar was not uniform. For 12 inches from the open front it was compact and good; back of this it became more porous with more frequent grains of coarse sand.

A very crude breaking test of sections of the slab was made when it was 16 days old (July 14), by standing in the middle of the sections; the sections were of different widths, according as

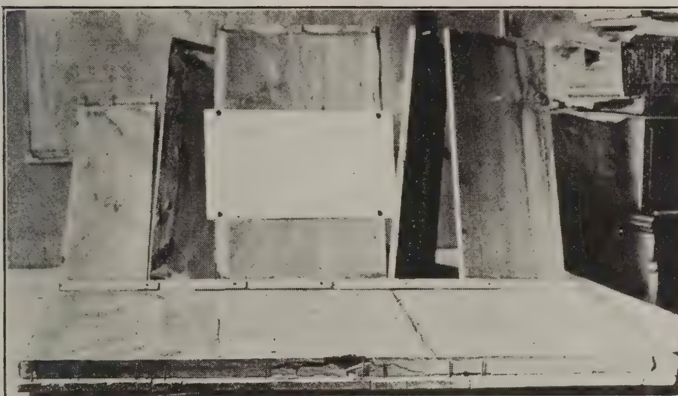


Fig. 5. Mortar Slab.

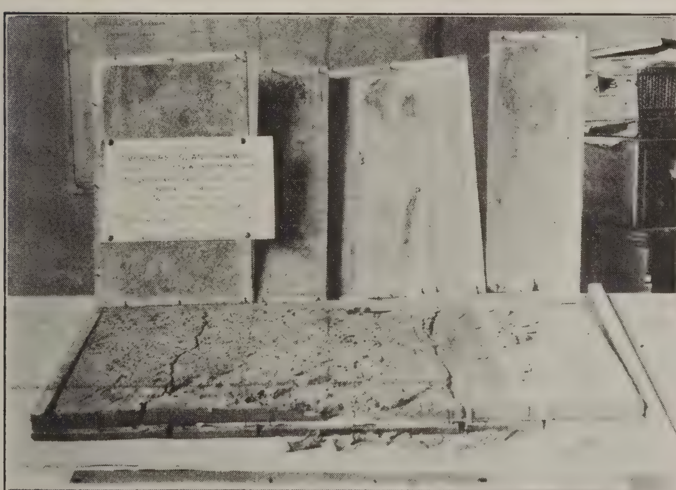


Fig. 6. Bottom of Mortar Slab.

the slab broke, each being a beam 18 inches long, 12 inches between supports, and 1 inch thick.

	Width on which pressure was applied.	Width of beam.	Approx. breaking load.	
			Total.	Per sq. inch.
	Inch.	*Inch.*	*Pounds.*	*Pounds.*
Section from inner end of slab	4	8	100	12½
Section from middle of slab	4	10	150	15
Section from outer end of slab	1	12	250	21

This is altogether too inaccurate for a test of the class of mortar; it gives a fair idea of the relative strength in different parts of the slab.

None of the mortar in the slab was really first class; it might be called fair. It filled the joints to an extent which could not be done otherwise.

Expenditures:		
Rental of cement gun	$250.00	
Rental of compressor	125.00	
Services of operator	150.00	
Services of compressor engineman	100.00	
Transportation, including 4 days' rental time	216.00	
		$841.00
Rental, 3 tarpaulins to cover cement		41.85
Services:		
Manisees and Ingalls and crew, freighting supplies and general assistance	$171.58	
U. S. inspector and overseer, with 5 to 7 men	641.09	
2 horses, carts, and drivers, 34 days	136.00	
1 double team and driver, 1 day	8.00	
		956.67
Materials:		
800 bags cement	$324.00	
125 28/100 cubic yards sand	91.71	
635 gallons gasoline	152.40	
Force pump, fittings, and hose for water	81.66	
Lumber, runways and mortar beds	59.76	
Tools: Wheelbarrows, shovels, sand screen, etc.	34.60	
Rope, for moving machines	24.09	
Miscellaneous: Canvas, rubber boots, etc.	39.48	
		807.70
Office expenses and travel	$258.93	
Photographs	7.45	
		266.38
Total		$2,913.60

This cost will be reduced by a rebate on cement bags returned in good condition; not yet determined, but probably about $60.

The value of materials and tools not used up on the work is estimated at $262.70. This will not far exceed the cost of removing them and storing them until needed, and must be regarded as part of the cost of work in a locality such as Governors Island.

The length of joints repointed, 22,320 feet, was measured, and is essentially correct. The open widths varied from 2½ inches to nothing, and the depths repointed from 36 inches to 3 inches. These can not be averaged with any accuracy, being almost wholly out of sight. It is roughly estimated that the average thickness of joint is slightly less than 1 inch, and the average depth perhaps 12 to 15 inches.

The cost of this work with the cement gun was not far from the cost for the same lengths of joint repointed by hand. Hand work would give a better finish, but would hardly extend more than 4 inches into the wall.

The cost on Governors Island is 10 to 15 per cent more than it would be at an accessible point in this city.

GENERAL REMARKS.

In operating the cement gun, a large supply of compressed air is needed. It is used to turn the cement and sand feed as well as to carry the dry mixture. This mixture will choke in the hose unless diluted with a large amount of air. From such observations as could be made, it appeared that the volume of sand and cement carried was from 1 to 2 per cent the volume of the air used as a vehicle.

The amount of water required was given by the Cement Gun Company as 5 gallons per minute, at pressure of about 45 pounds. This quantity was seldom used, and the stated pressure is not needed. The suction from the air blast would draw in the water if delivered at the nozzle under a much lower head.

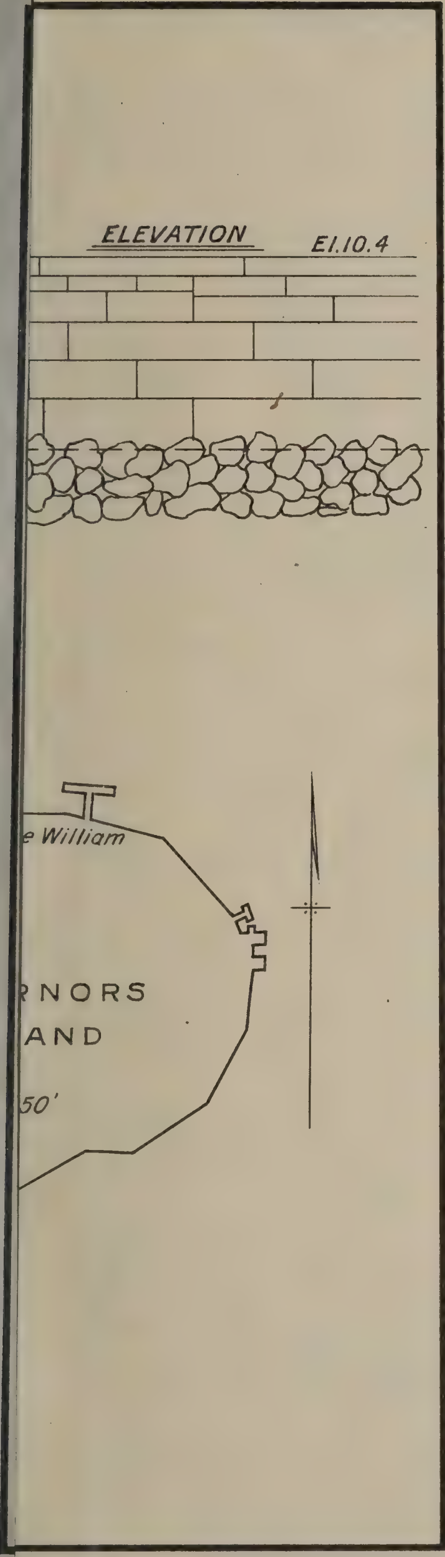
At Governors Island, fresh water could not be had along the line of the sea-wall; and salt water from the bay was used, pumped up through a fine brass mesh.

After One Winter's Exposure.

This report has been withheld to ascertain whether the joints were filled by the cement gun sufficiently to prevent damage from water freezing in the joints.

An examination was made October 9, 1916, and another May 17, 1917. In neither case was there found any deterioration since the repointing was done. For about half the length of wall repointed, the lower joints, at and below half tide, are from 2 to 3 inches slack; and for a length of 125 feet, near the light-house, the lower joint is from 10 to 15 inches slack. This 125 feet was repointed June 22, 1916, when the sea from a strong northwest wind washed the mortar out while it was fresh.

On May 17, test drills were driven 6 inches into the joints at these places; the mortar was everywhere firm and very hard. With hand pointing, the joints would not be filled to a depth of 6 inches.

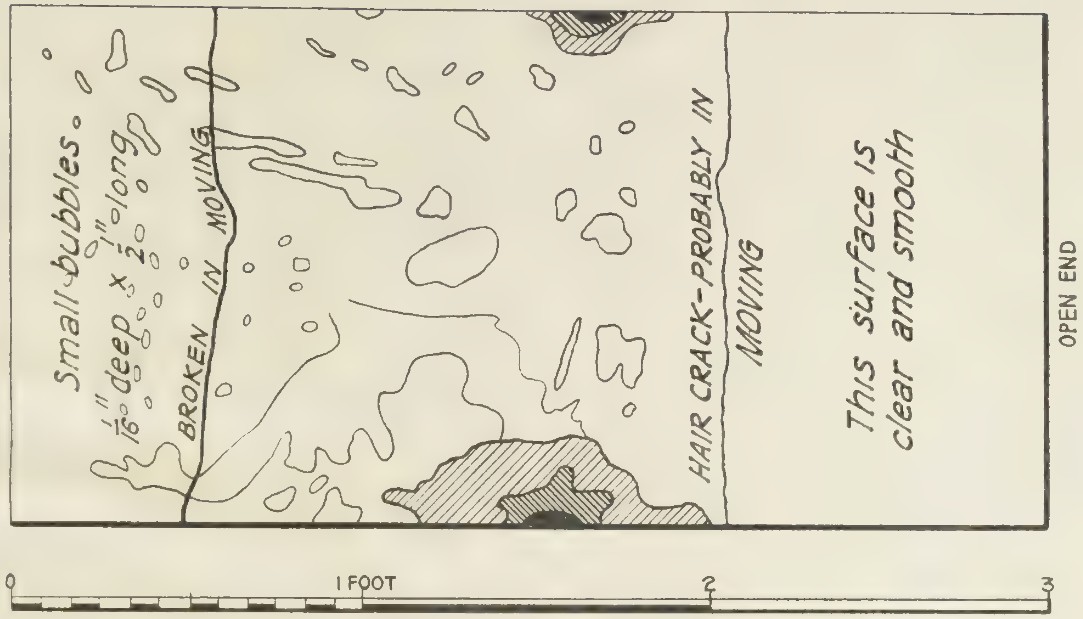


ELEVATION
El.10.4
e William
RNORS
AND
50'

GOVERNORS ISLAND SEA WALL

CEMENT MORTAR SLAB

36" x 18" x 1"



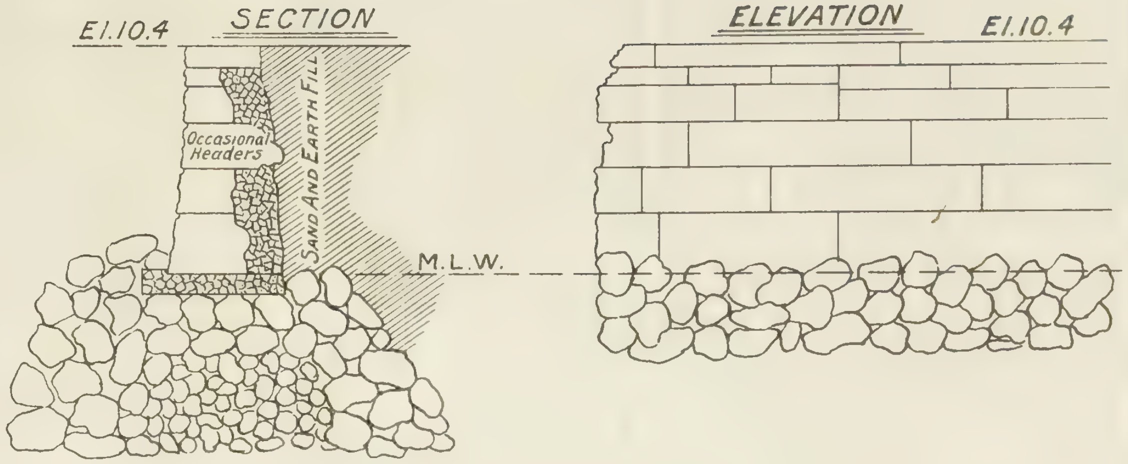
Upper side, as shown

Solid shaded areas - empty clear through - 1 inch deep
Heavy " " ½ inch depth or over.
Light " " ¼ " " " "

All of these spaces were filled with sand - not cemented in.

Areas inclosed, not shaded, are from 1/16 to 1/8 inch below the surface and smooth on top, as if they had been water bubbles which dried out.

The bottom of the slab showed no bubbles or sand pockets and presented a smooth surface.



Scale: 1" = 10'-0"

Scale: 1" = 1250'

Concrete Wharf Supports in San Francisco Harbor.[1]

BY

Mr. Thomas S. Williams,
Board of State Harbor Commissioners, San Francisco, Cal.

San Francisco Harbor is situated on San Francisco Bay, which is connected with the Pacific Ocean by a strait called the Golden Gate, about 3 miles long by 1 mile wide. The waters of a number of large rivers eventually find their way into the bay, nevertheless, on account of its size and proximity to the ocean, its waters are substantially as salt as the sea. The result is that salt-water marine borers, known as teredos and limnoria, familiar along the entire Pacific Coast and elsewhere in the salt waters of the globe, infest San Francisco Harbor, likewise, and on account of their destructiveness to wooden piles in their natural condition it has been found necessary by various means to guard against their depredations.

Different woods, pine, fir and eucalyptus have been tried, but all proved unavailing.

Different methods of wrapping and otherwise preserving the natural wood, some of them patented, were used without satisfactory results.

An untreated wooden pile of fir or pine will last only about a year. The borers are fastidious enough to prefer clear salt-water, consequently muddy water or water fouled by sewage is some protection to the wood. It is, however, substantially accurate to say that the life of a green pile is only a year.

A creosoted wooden pile lasts, according to the clearness of the water, from fifteen to twenty years, but, of course, great care must be exercised to secure piles that are properly creosoted, not only as to the materials used, but as to the processes employed.

Finally, experience has forced us to settle in practice at the present time upon two main types of wharf supports; first, creosoted wooden piles, second, concrete supports.

Notwithstanding that concrete construction is from two to three times as costly as creosoted wood, our present practice is to use concrete wherever the foundation conditions permit.

As is well known, the great advantage claimed for concrete is its durability. Frequently we see it described as "permanent" construction, but experience with this class of construction either in San Francisco Harbor or elsewhere under modern traffic conditions, has not been sufficiently long or varied to permit of a sure

[1]Reprinted, by permission, from the "Proceedings and Papers of the Fifth Annual Convention of the American Association of Port Authorities" (Vol. V, Paper No. 2), held at Montreal, Can., September 13-15, 1916.

deduction as to just how "permanent" even the best concrete is.

Being a manufactured article composed of various ingredients, mixed in varying proportions and by different methods, all concrete is not the same. Some of it is good; much of it very bad.

Moreover, the chemical action of salt-water upon even the best concrete is a mooted question among engineers. Whether such action is deleterious, in periods short or long, I do not undertake to discuss, but the result of twenty years' experience with concrete in San Francisco Harbor shows that on good concrete no appreciable adverse effect due merely to the action of salt water has become visible.

Likewise, electrolysis, due to escaping electricity, is said in some localities frequently to have rapidly deteriorated the steel reinforcing rods used in concrete constructions and thus contributed to the disintegration of the concrete.

Of the alleged effect of electrolysis, we can furnish no evidence from San Francisco Harbor, because steel reinforcement is of so recent use that data on the point mentioned are not forthcoming. Our practice now is never to use concrete unless reinforced by steel rods.

Concrete supports, used in our piers, wharves or sea-walls, have been of two main types, one called cylinders and the other piles, the striking difference between the two being that the cylinders are put in as wet concrete fresh from the mixer and allowed to set in position inside of a wooden frame, whereas the piles are manufactured on shore, thoroughly seasoned by being allowed to set at least thirty days and frequently as long as sixty days, and then are driven into position by a pile-driver or steam hammer. Frequently it is necessary also to use with the hammer the aid of a water-jet, which is employed where certain hard bottoms require it.

I shall describe the concrete pile first, and afterwards the concrete cylinders, with a brief reference to our experience with both.

When I mention piles hereafter, please understand that I have reference only to this character of pile, made of concrete and thoroughly cured on shore and then carried to the work and driven into position.

The use of such a pre-moulded concrete pile in harbor construction is comparatively of very recent origin. We are not aware just where it was first employed, but San Francisco is, at any rate, among the pioneers in its use. We doubt whether any other American harbor has used them as freely. They were first driven in that harbor in 1911, at first rather gingerly for work close in shore, but, emboldened by apparent success we gradually extended their use until we are now able to exhibit a new pier just completed, 200 feet wide and 900 feet long, entirely supported by concrete driven piles.

The first piles used by us were 66 feet long, 16 inches square, and were employed to sustain concrete masses under ferry aprons.

In a pier just completed the length of piles varies from about 40 to 106 feet, and they were placed with centers 11 by 12 feet apart.

The pile is reinforced with longitudinal steel rods, four of them,

each five-eighths of an inch square, being set in piles 16 inches square and from 35 to 40 feet long, and eight rods each 1 inch square in piles 20 inches square and from 90 to 100 feet long.

In order to facilitate driving, the piles are given a taper, beginning about 10 feet from the point, tapering to 10 inches square.

In setting the reinforcement, soft steel wire, one-quarter of an inch in diameter, is wound spirally around the rods, with spacing for the wire of about 6 inches.

It may be of interest to state that one of these piles, 20 inches square and 100 feet long, weighs about 20 tons.

In designing such a pier it is necessary to drive test piles of wood in advance, so as to determine bottom conditions. Borings are also made. In the plans, the length of each pile is specified. If it turns out to be too long when actually driven to refusal, the top of the pile is blasted off with dynamite, and if it turns out to be too short, it is built up by concrete to the proper level.

A question may arise in your minds as to the difficulty of handling without marring such a long and heavy pile. On the contrary, with a proper pile-driving rig it is marvelous to see how deftly and safely the pile, grasped at three or four points by wire ropes, is dragged and lifted along the wharf or sometimes from shore to barge, and thence hoisted into driving position.

As a long pile, frequently 90 to 100 feet in length goes into the air, it is most interesting to note what elasticity it possesses, shown by its bending and flapping like a monster whip, but straightening out most perfectly when it is set in the pile-driving frame.

Another question may arise as to possibility of fracture in hard driving. Here is shown the most astonishing result. Local engineers who have made observations during the process of driving, have repeatedly confessed to us their amazement that the pile can stand the powerful hammering it receives with almost perfectly satisfactory results. Generally speaking, not a crack, big or little, is visible.

The top of the pile, during the driving, is protected by a rope cushion and a wooden block about 6 inches thick, and usually the point is not protected at all. It might be supposed that the point, under such circumstances, would spread out or mushroom, but such is not the case, even in hard compacted sand or clay.

In sea-wall construction, however, where we first put in at base a loose rock fill and then drive such piles through the rock as supports for the deck or bulkhead wharf, a hole is made for the pile by driving a wooden "bull-dozer" ahead of it, and the point of the pile is often protected by a steel shoe.

Thus far we have driven piles only into good, firm holding-ground, securing usually a penetration of about 30 to 40 feet.

Much of our water-front is very soft mud, running frequently to a depth of 100 feet or more, before stiffness is found, and in such regions the concrete pile has not yet been used.

Sometimes the depth of the water at the outer end of our piers puts a limit on the length of piles practicable in such locations.

Results already obtained in handling piles up to 106 feet long and 20 inches square are encouraging us to try even larger piles in some contemplated work, and very likely before long piles 115 and 125 feet long and 2 feet square may be tried. Of course, such piles will necessitate specially built drivers.

Comparing such concrete piles with concrete cylinders, it must be acknowledged that the piles to the lay mind give a most satisfying sense of real strength and durability. You see them made, you can examine them, you know whether there are voids or not, you see them hauled and lifted into position and stand hammering of tremendous force, and you go away with a feeling that that particular thing will stay put for a long, long time. You have all the gratification that comes only from ocular demonstration.

One does not get the same consciousness of sureness from the cylinder type, especially where the concrete cylinder is supported under the mud by wooden piles, which is necessary in the absence of a sufficiently hard bottom to sustain the loads.

Let us turn now to the cylinder form of concrete supports.

They may be divided into two main types as used in the harbor of San Francisco.

The first type was introduced about fifteen years ago and has been entirely abandoned because of its deficiencies, manifested by the lapse of time in many piers.

The composition of this type was as follows. Wooden piles, sometimes one, sometimes three close together, were driven to refusal, the tops coming up to near the wharf deck, then a wooden stave form of cylindrical shape was placed around them and driven into the bottom, no steel reinforcement being used, and then the concrete was poured in and allowed to set as best it might. Generally speaking, the mud was too deep to permit one to say that there was any bed-rock or hard bottom at all under this construction. Such cylinders were about 3 feet in diameter.

It will be seen that in reality this type could be best described as a wooden support, protected by concrete, because the wooden piles carried the load of the wharf and also sustained the concrete, the theory being merely to protect the wood from marine borers by the casing of concrete.

To be clear, I may add that these borers can not live below the mud line, and, of course, it is well known that wood while covered by water or mud will last indefinitely.

The design of such cylinders, which almost uniformly proved failures, contemplated that the bottom of the concrete would extend about 2 feet below the mud line. The calculation was that this was sufficiently deep to guard against shifting or other removal of the mud, that might in consequence expose the wooden piles to the attacks of the voracious teredo.

This calculation proved futile. Modern vessels with their swift and powerful propellers, raised such a disturbance of the waters, that the mud was whipped or sucked away from the supporting wooden piles, the teredos thereupon honeycombed them in short

order, and the concrete columns above them necessarily fell into the water. This was a common occurrence in piers so designed.

Such cylinders were all built without steel reinforcement, but the absence of the reinforcement was manifestly not the particular cause of failure in this instance, as the whole cylinder fell when the wooden supports were eaten off by the teredo.

Another serious mistake, with costly consequences, was made by pouring the wet concrete mixture into the cylinders without removing the water from the bottom of the form. The result invariably was that such wet mixture deposited in water never did set into true concrete at all, since the cement was practically washed out of it. Disintegration of the bottoms of such cylinders followed rapidly.

We have mentioned the faulty design, due to not putting the end of the concrete cylinder deep enough into the mud, and we have mentioned the ignorant method of depositing the concrete mixed into water at the bottom of the form, and when we add the fact that probably the mixture itself was often bad or defective in its cement or rock or other ingredient or in the proportions employed, we have accounted for the resulting condition of such cylinders, which for the most part were costly failures.

From these causes about 25 per cent of our piers went out of commission in the past four years, such piers varying in age from six to twelve years.

It was impossible to repair them with concrete and substantially they had to be rebuilt with creosoted wooden piles driven in and set with considerable difficulty and cost under the existing wharf decks and sheds.

Profiting by the experience of their predecessors, our engineers in the past four years have improved on the old type of concrete cylinder and in the actual work of installing them in several noticeable respects, and have employed what we may designate as our second type of concrete cylinders.

This type is really founded on an entirely different principle.

If wooden piles are used to support the cylinder, as they must be in mud bottoms where there is no bed-rock, the piles are driven to about 8 feet below the permanent dredge line and come up into the concrete cylinder only about 5 feet, the theory being that the wood supports the cylinder and then the cylinder supports the wharf. This arrangement, we believe, guards sufficiently against the possibility that the wood will by shifting of the mud become exposed to teredo attacks.

The method is first to drive a steel shell, or caisson, in cylindrical shape into the bottom, so that it can be sealed. The mud is dredged out of it and the water pumped out, and the wooden form with the steel reinforcement already set in it is lowered into the steel shell. Great care is taken to clean and dry the bottom of the form as thoroughly as possible, and then the concrete mixture is poured in and tamped down by hand.

After the concrete is set, the steel shell is pulled off by the pile-driving apparatus and again used elsewhere.

Steel reinforcing rods are always used, usually three-quarters of an inch square, and from 8 to 12 rods in each cylinder. The concrete columns when finished are from 3 to 4 feet in diameter.

Spiral wire hooping is also used around the reinforcement, as already described with respect to the concrete piles.

The mixing of the concrete is carefully inspected by competent inspectors of our own selection; the cement, steel and concrete are tested by our testing engineer; and the cement is bought by us and furnished to the contractor for the work.

It may be of interest to add that in the concrete mixture now used in the harbor of San Francisco the proportion of cement to the aggregate is 1 to 5 in the pile, and 1 to 6 in the wharf deck and cylinders.

Our experience with cylinders has warranted the deduction that where at all practicable the cylinders should rest on bed-rock, thus avoiding the use of wooden supports below them. By bed-rock, of course, we mean any bottom hard enough to carry the load.

In San Francisco Harbor, as far as it has been improved, such bed-rock has been found in only one limited district, and in that stretch seven piers have been built, supported by concrete columns or cylinders of the type last described, and going down to hard-pan and without any wooden supports under them at all. These piers range from 130 to 200 feet wide and from 650 to 800 long.

Our pier-head line is limited by the United States government to a distance of 800 feet from the sea-wall or shore line bulkhead.

Where a greater length of pier than 800 feet is desired, the object is accomplished by inclining the pier at an angle to the sea-wall, thus affording some berths of over 900 or 1,000 feet in length.

The minimum depth of water is 33 feet at the bulkhead line, which depth is enjoined by statute, and the depth at the outer end of the pier averages over 50 feet, and in a number of cases is as much as 70 feet.

It happens that the best bottom is in the district where the water is deepest, and consequently the construction of piers resting on concrete cylinders going down to bed-rock in this district was necessarily very expensive.

Some idea of the quantities involved in building such a pier, 200 feet wide, 800 feet long, in water much of it 50 to 60 feet deep and supported by concrete columns 3 to 4 feet in diameter, may be gathered by reflecting that the outer end of the pier would be as high as a five-story building; and with a shed on top of that about 35 feet high.

If the depth of water is not too great and the bottom is of such character as permits us a choice between concrete piles and concrete cylinders as wharf supports, experience with both types has brought us to a decision in favor of the piles. As I have said, we feel better satisfied that we know what we have got.

In short, where bottom conditions permit, we exercise a preference in favor of concrete over wood, however treated or protected; and when it comes to concrete we prefer the driven pile type to the built-up cylinder type.

The German Shelters on the Somme.[1]

On each great offensive movement, the official *communiqués* inform us that the progress of the advance has often been impeded and sometimes stopped by a "*fortin*" (fortlet) or a redoubt. It must then wait for the artillery preparation.

What then is a *fortin?* In this war, full of surprises, it is very certain that the old conception of this piece of fortification applies to tactical ideas very different from those of to-day. A *fortin* is now a closed work, either isolated, or shut off by a barricade, improvised by the defenders in a position they have partially lost. This work is in general composed of elements of trench barricaded toward the lost ground (this is called the *cloisonnement*), provided with one or many shelters proof against shells of great caliber and defended by a garrison well supplied, and determined to fight to the bitter end.

The essential element of the *fortin* is the bomb-proof shelter. It protects the defenders who, after the artillery preparation, will occupy it and resist for many hours and sometimes for many days, an assault in which several successive lines have been submerged.

Last summer, the offensive on the Somme gave us a chance to see and study certain shelters which our enemies had built and utilized during a long period of relative tranquillity. These shelters were proof against all but shells of great caliber with long delay-action fuses; the struggle still keeps on between the shelter and the heavy gun.

What is the effect of the explosion of a percussion shell, first in the ground, and then on the bomb-proof shelters? What dispositions have been made against the increasing and rapid development of heavy artillery? From the brief description, with sketches, of the German trenches which we have visited on the Somme, we can clearly define the principles which have governed their construction.

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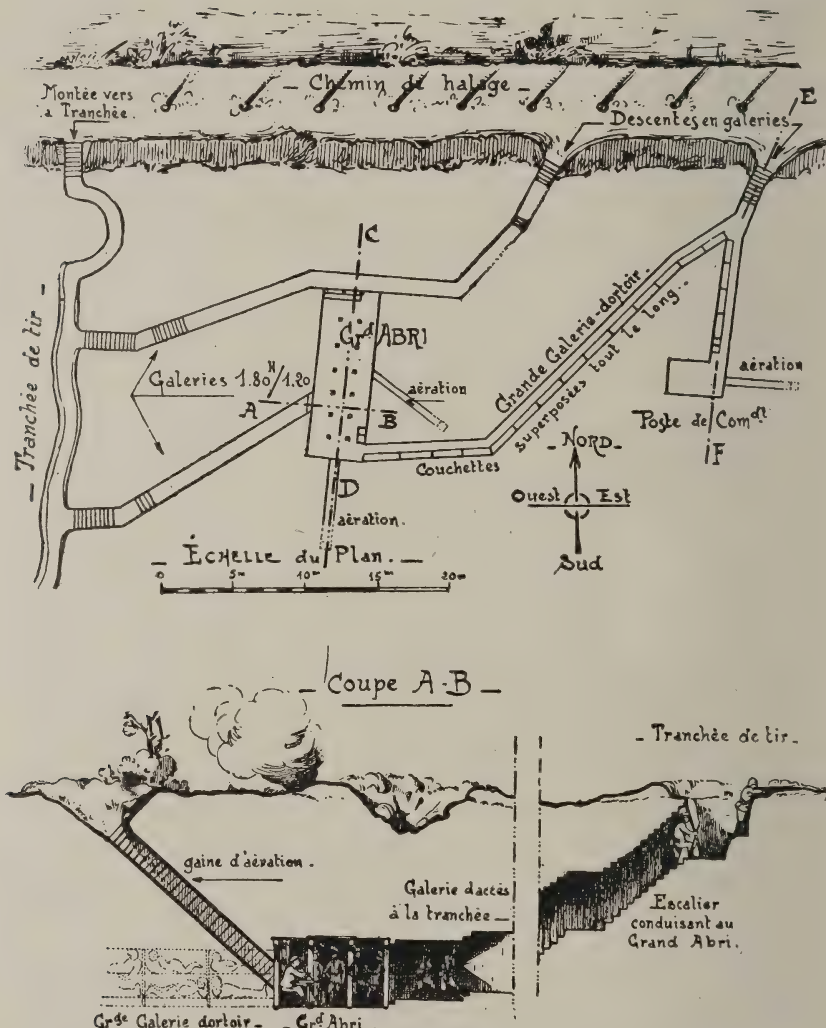
[1]Translated from *L'Illustration*, January 13, 1917, by Col. W. R. Livermore, U. S. Army.



GENERAL PLAN AND CROSS SECTIONS OF A GREAT SHELTER

Ascent to the Trench. Tow Path. Descent to the Galleries.

GRAND SHELTER.

Firing Trench.

Galleries. Ventilation Great Dormitory Gallery.

Cots superposed all along

Ventilation. Command Post.

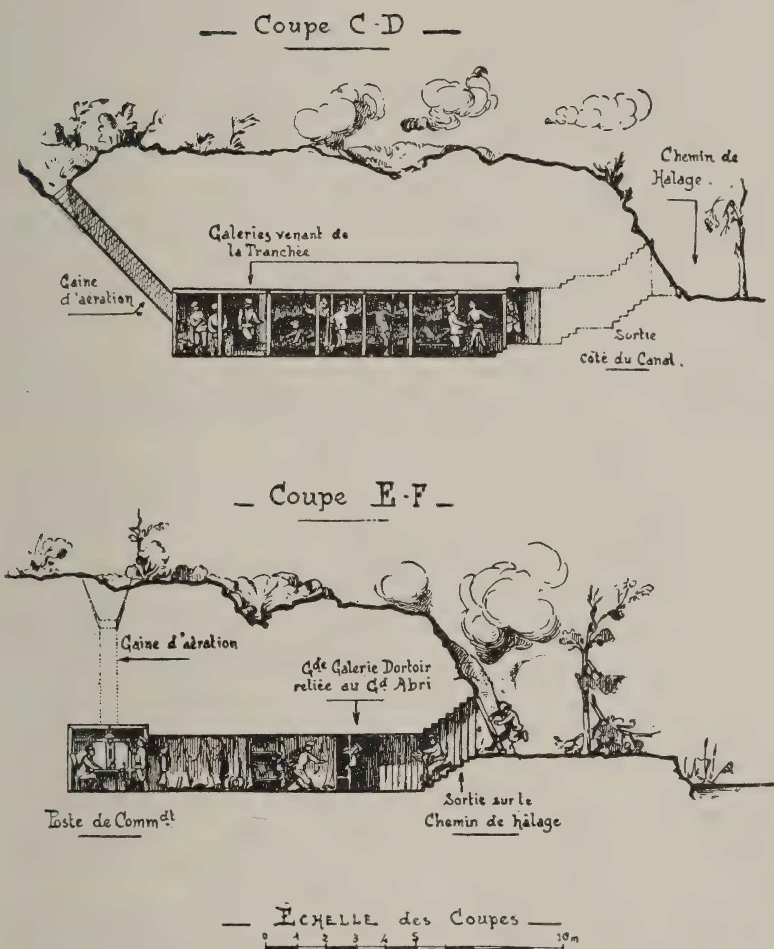
SECTION A. B.

Firing Trench.

Gallery of Access to Trench. Staircase leading to the Grand Shelter.

Shaft for Ventilation.

Great Dormitory Gallery.



WHICH THE GERMANS DUG IN THE REGION OF FRISE.

SECTION C. D.

Galleries coming from the Trenches.

Shaft for Ventilation.

Exit.

Side of the Canal.

SECTION E. F.

Ventilating Shaft.

Great Dormitory Gallery connecting with the Grand Shelter.

Command Post.

Exit to the Tow Path.

Shelters, proof against the formidable bombardments employed in the present war, are established in the several lines of the successive positions of every sector. Against heavy artillery, special defenses are required which it takes a long time to prepare. A large caliber shell buries itself deep in the ground and at the moment of its explosion produces a funnel shaped cavity. But the effect of the deflagration is not limited to this yawning crater, which is all that remains after the great cloud of smoke is cleared away. The effect of such a shell is in every way like the explosion of a "concentrated" mine.

The shell fired at long range from a heavy gun, mounts at first high in the air and then falls with a characteristic whistle, striking the ground at a great angle and with considerable living force, at last buries itself to a depth "H" beneath the natural surface as far as the point "O." The depth "H" will be greater or less, according to the resistance of the soil and the living force of the shell. Of course, it must have a delay-action fuse or it would explode the moment it touched the ground.

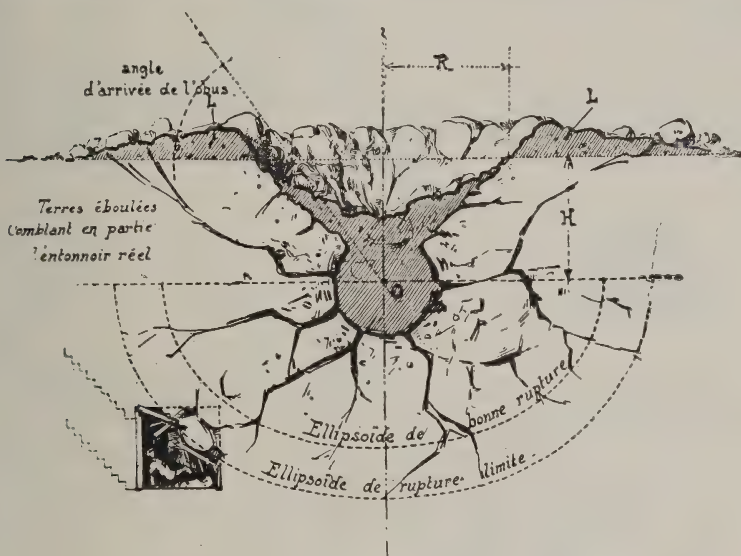
If the charge is sufficient, the earth is raised in a sheaf to a variable height and a crater is left more or less filled with the earth and fragments that fall back.

"R" is the radius of the crater, the lumps thrown out to "L" forming the lips. According to the ratio of the radius to the height "H" we have an ordinary mine, an overcharged mine or an undercharged mine. If, on the other hand, the charge placed at "O" is so small as to show no effect on the surface, it is called a camouflet. The shell bursts deep in the ground, and the only damage is subterranean. Only percussion shells with long delay-action and with great living force when they strike the ground, produce such effects. They are meant to destroy sunken shelters. Their explosion gives only interior effects concentric around the point "O."

Against concreted shelters or those strongly reinforced with compound metallic girders and as a rule slightly sunken, shells of large caliber with base primers are generally used. Their very murderous blast is much more potent as the explosive bursts nearer the surface of the ground. It acts at great distances, destroys everything, sweeps the collateral defenses, buries the slightly protected entrances to the shelters, bursts the roofs, doors and windows of the houses, breaks the panes, puts out the lights, and cases of insanity and deafness are frequent with those who have been exposed

to its action at short distance. Often in a shallow shelter men are wounded or even killed by the action of the blast alone. To break the blast the entrances are disposed "*en chicane.*" Such are the effects produced by shells of great caliber. Because of their destructive power they are used to annihilate forts and redoubts, the shelters or nests for machine guns of reinforced concrete, fortified houses, boyaux, shelters of all kinds, and also to counter-batter the enemy's batteries. As the guns and shells have grown heavier and heavier, the defences have been developed with equal pace.

The German shelters by the number and the care with which they are constructed show their wish to protect themselves effectively against heavy artillery. Varied as they are in detail, they show common characteristics which indicate rule and discipline.



Our enemies bury the shelter, properly so called, the living room, below the limit of rupture. Fig. "A" gives an idea of the effect of a shell of large caliber on a shelter in the field of action of its explosion; and we see at once how deep the shelter must be built to escape it.

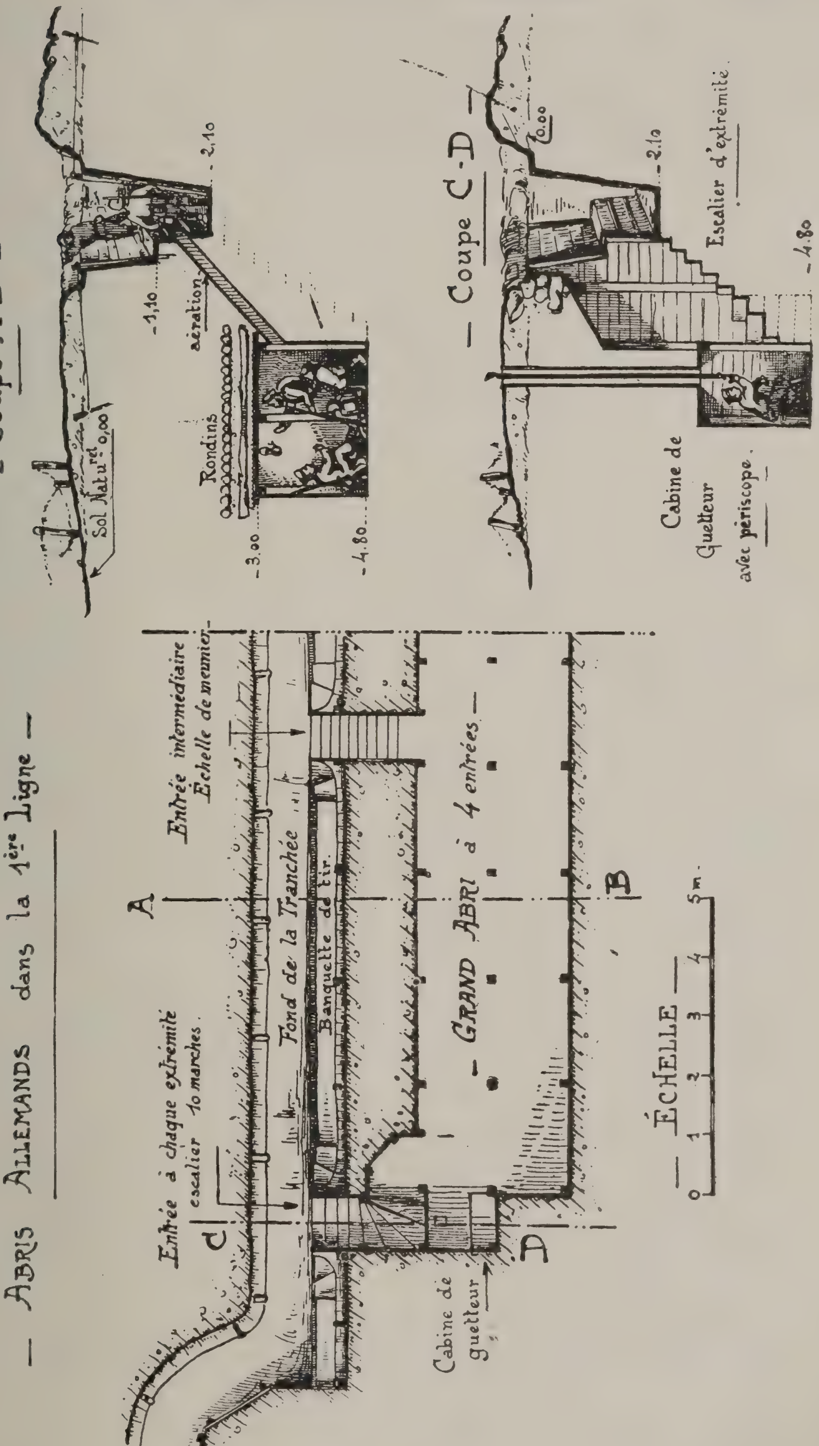
In the natural shelters like caves, or in houses prepared for defense and redoubts, the Germans employ a protection of resisting material, called a bursting bed. It is composed of several layers of large logs, separated by several layers of sand-bags. The logs

are sometimes replaced by double T-beams of metal, by masonry or concrete. The bursting bed stops the shell and prevents its penetration into the shelter. The projectile then bursts on the surface. and its interior effects are almost none.

The Germans show great care and method in the construction of the shelters. They hide them by not making great piles of excavation and by leaving to the trench its general form at the approaches to the entrances.

Every well marked shelter can, in fact, be surely destroyed if direct fire is possible.

Our enemies have felt that, in spite of every precaution in designing their shelters, the entrances would always remain very vulnerable to heavy artillery and, for most of the time, to the percussion shells of the field artillery. They have therefore increased the number of the outlets, and have added chimneys for ventilation and relief, in which a man can pass in the prone position. All these entrances are so far apart as not to be destroyed by the same shell.


— Abris Allemands dans la 1ère Ligne —
— Coupe A-B —
Sol Naturel 0,00
-1,10
aération
2,10
Rondins
-3.00
-4.80
— Coupe C-D —
0.00
2.10
Escalier d'extrémité
-4.80
Cabine de Guetteur avec périscope.
Entrée à chaque extrémité escalier 10 marches.
Entrée intermédiaire Échelle de meunier
Fond de la Tranchée
Banquette de tir.
— Grand Abri à 4 entrées —
A
B
C
D
Cabine de guetteur
— Échelle —
0 1 2 3 4 5m.

Uniformly, in all their types of shelter the Germans descend by staircases sheathed with mine-casing.

Some *fortins* constituted by shelters, or typical "command-posts," have served as centers of resistance for our adversaries in the course of the offensive of the Somme. We have visited some at Herbecourt, at Frise, and at Biaches. Certain of these dens appear to have been abandoned without opposing serious resistance.

One of the most curious is an immense shelter which the Germans had dug along the Somme Canal to the west of Frise. On the slope of the canal were two entrances, made with great logs, solidly buttressed. This shelter was built with some care, cased and planked. The rooms were furnished and floored. A tier of cots was placed along one side of one of the galleries. Two other galleries came out in a trench which faced toward Frise.

A very different kind of shelter in section is made of arched sheet iron and deeply buried. In certain trenches the Germans established series of eight shelters of this type, 8 meters long and 2.80 meters wide and 2 meters high to the key of the arch. They have wooden floors. Two curved passages open on the trench in the splinter-proof at points so far apart that both can not be demolished by the same shell.

Finally, we find the ordinary shelter as a mine gallery, with at least two descents by staircase. This is the most common type, which we have already described in a preceding article. The Germans make it deeper and deeper, even to 8 meters below ground. This type is designed for a garrison of a half section.

With shelters thus buried, eventual embryos of *fortins* and redoubts, we can conceive that it is very hard to destroy the essential works of the enemy's defense. They are almost always so well concealed that nothing reveals their presence. We must, then, resort to a zone fire over all the region where, from the prisoners or the aviators, we have learned to locate them. Then, in spite of the incredible expenditure of ammunition, we still find numerous shelters intact, and some defenses which have defeated the cannon because they have never been found. These defenses are veritably "devil fish," which suddenly emerge in the great ocean of iron and fire of modern artillery preparation. They rapidly stretch out all their tentacles through the neighboring trenches and boyaux, sometimes forming those little centers of resistance of which so often our infantry runs foul.

If the *fortins* do not fall in the fury of the first assault, they must then be invested and the progress much impeded and delayed.

A Visit to the English Front in France.[1]

BY

Capt. D. VICTORIANO CASAJUS.

The battle of the Somme, at one point of which we were present, began, and still continues, the first part of July of this year, with a general and simultaneous advance of the French and English troops along a front of from 30 to 35 kilometers, and in a sector embraced between the rivers Somme and Ancre, the latter its tributary on the right.

This battle represents the culmination of English effort after the reorganization of their army, and is, it would seem, the most fiercely contested that has occurred up to the present time along the whole western front since the war began; and it illustrates, so far as we can with any degree of certainty judge, as no previous actions do, the character of the struggle inaugurated in this theater of war, showing a complete change in military tactics, into which it will be necessary for us to go more fully in detail; always with certain natural reserves [such as may be imposed by censorship and the sacredness of military confidence].

The front with which we have become familiar exhibits in essence the application of old systems of siege operations applied to a continuous line of fortifications some hundreds of kilometers in extent, with such modifications as are naturally required to meet the demands of the methods of warfare as at present conducted. And these have brought into sharp contrast the manner of employment of arms, which was theoretically maintained before the war began, and that which has come to be established under the peculiar conditions of the struggle as it actually is. It is to be understood that we propose to offer to the reader a consideration of war and the preparation therefor as learned from the point of view of actual observation. It may be, however, that some of the conclusions arrived at may need to be modified, when the true story is known of the entire operations, and of its fullest details.

In brief, the impression gained from our observations is that the artillery, with the aid of chemical agents, along with the gasoline motor, available both for the conquest of the air and for the

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[1]Translated from "*La Guerra y su Preparacion,*" *Estado Mayor Central, Ano 1 Numero 8,* Madrid. December, 1916. Translated by Maj. Henry Swift, Chaplain, U. S. A., retired.

enhancement of land transportation, have completely changed the face of war.

I will begin, then, by treating of that which in my judgment plays the most important part in this change, namely, the artillery; for after a careful analysis of all the modifications that have been made in the various branches of service, our conclusion is that they are largely due to the two factors mentioned.

ARTILLERY.

The cannon has advanced by leaps and bounds beyond the limits of what used to be ordinarily expected of it; the German army having been pioneers in inaugurating this advance, with the increase in power.

Two distinct theories were maintained before the war as to calibers. These schools were represented, respectively, by France and Germany. The French believed that the field gun, with the maximum rapidity of fire possible, would be effective against pieces of heavier caliber: provided that they were employed in sufficient number: and with them the tendency was to adopt a good field-piece, available for every kind of service, that is to say, at the expense of or the reduction of the caliber. In the meanwhile the Germans, without ceasing to believe in the usefulness of guns of small caliber, maintained the theory that these should be reinforced by a considerable number of heavy pieces and by howitzers, both to counter-batter the light field-guns of the enemy and to demolish the works which the troops might improvise, having the additional advantage of a longer range. The result of this was, that at the beginning of the war the German batteries of heavy guns, used as counter-batteries, and aided as they were by aeroplanes, destroyed whole groups of artillery on the opposing side, these being of lighter caliber, and failing to hide themselves, as to-day they have learned to do; their thought then having been only that of inflicting the maximum of injury on their adversaries.

And it was the belief, even up to the present time, that guns of calibers greater than 6 inches (15 cm.) were available only for demolishing permanent fortifications, that it would not be possible to transport them with armies operating in the field, nor to supply them conveniently with the ammunition required. However, all these ideas have proved to be fallacious. The real truth was demonstrated when the Germans and Austrians conveyed along with their armies howitzers of 27, 30, 38 and 42 centimeter caliber, which they employed, not only to destroy works of a permanent character blocking the path of their operations, but also against the supply depots along their lines of communication, villages and towns where their troops were quartered, barbed-wire entanglements, and other obstacles.

Lessons so drastic could not but be well laid to heart, and the English army in France set to work without delay to prepare itself for a struggle, which so far had proved to be unequal, because

of deficiencies which the Germans had demonstrated to them, and which they prepared to rectify at an enormous expense.

In consequence, instead of the hundred pieces, with which the first expeditionary English forces had landed on the continent (of which only 18 were howitzers with a caliber of 11 cm., and 4 heavy guns of 12.5 cm.), which gave only 1.66 pieces to every thousand men, while the proportions with the Germans was 6.4, they have created for the offensive on the Somme an artillery which is far different from the rudimentary equipment which they had at the beginning of the war. The effects of this armament may be judged from the aerial photographs which are given in this article.

Judging from what we ourselves have seen, and from informa-

Fig. 1.

tion which we have been able to gain from others, they have to-day along their front, besides their field-pieces of 8.4 cm., guns of 5 inch (12.7 cm.) caliber having an effective range of 9,140 meters, 6 inch (15.2 cm.) howitzers which send a projectile of 55 kilograms a distance of 6,400 meters, howitzers with a caliber of 9.2 inches (23.3 cm.) with a projectile weighing 131 kilograms, and with a range of 9,000 meters, as well as 11 and 12 inch howitzers (27.9 and 30.5 cm., respectively), and even naval guns of 15 inch caliber (38.1 cm.), which are conveyed on rails, sending a projectile of 770 kilograms 11 kilometers at the possible rate of one shot a minute. Formerly such pieces were only to be found on board of war vessels, and in important strongholds. To-day they assist in the work of destruction of the shelters and covers of the enemy. (See Figs. 1 and 2.)

STRENGTH AND EQUIPMENT OF THE ARTILLERY.

As to details concerning the number of guns . . . ? These, as might be expected, are not known to us; but the natural inference is that the equipment of the artillery would be commensurate only with the limits of national production. On account of the stationary character of the struggle along this front, the principal difficulty which ordinarily exists in an excessve lengthening of the columns of artillery is not here in evidence, nor is the occupation of a space of ground occupied by this arm disproportionate to that of other branches of service; for as a rule the pieces are generally distributed over a considerable depth.

Furthermore, it is known that, by reason of improvements in matériel, giving to the guns greater effectiveness and mobility,

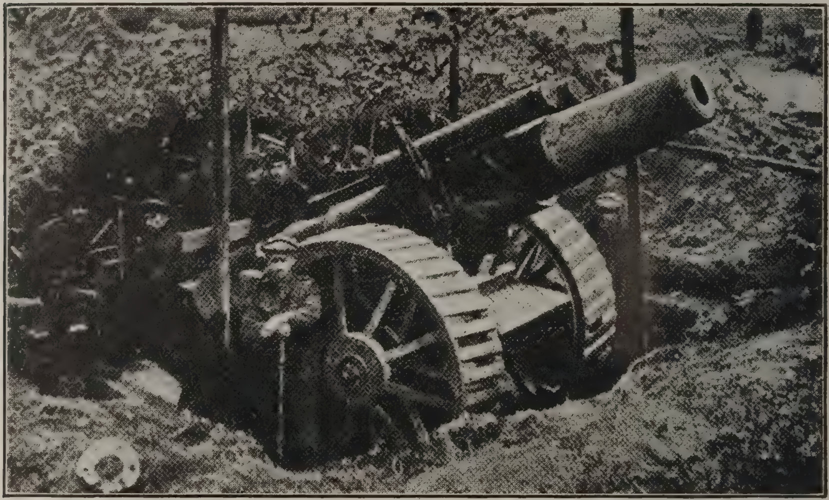

Fig. 2.

that the supply of these has been greatly increased. And so now, whenever the decisive moment arrives, we find them right on the spot, as we shall have occasion to note presently.

And here the internal combustion (gasoline) motor appears as responsible for the transformation to which reference has already been made. Thanks to its agency, all the heavy pieces which I have enumerated, with the exception of the naval guns, and those only of the highest power, can be transported from one point to another. Those of lesser caliber than 9 inches (22.5 cm.) are mounted on gun-carriages, their wheels being provided with shoes which cover or shield the tires (see Fig. 3). Those of a greater caliber, which need to be set on a platform, are carried on two or more trucks, drawn as a train by a tractor engine. These pieces are the same that in former times, as we look back on the experience of the past, were reserved exclusively for siege operation.

MECHANICAL TRACTORS.

The model most in use, which had been experimented on already before the war, is the "caterpillar," a machine invented in North America, shown in Fig. 4. The motor wheels are elliptical, and are enclosed in an endless chain which, by covering a broad surface of adherence, prevents the wheels from being mired or stalled in soft ground.

The capacity of this machine for crossing the country is something marvelous. It can pass over ditches a meter and a half in width, and when it comes to a wall or parapet of earth obstructing its progress. it raises its front portion, climbs the obstacle, and descends slowly on the other side. We have been assured that thus it has been able to surmount obstacles 3.5 meters in height. Its weight is about 8 tons, and it can draw a net cargo of 5 tons over

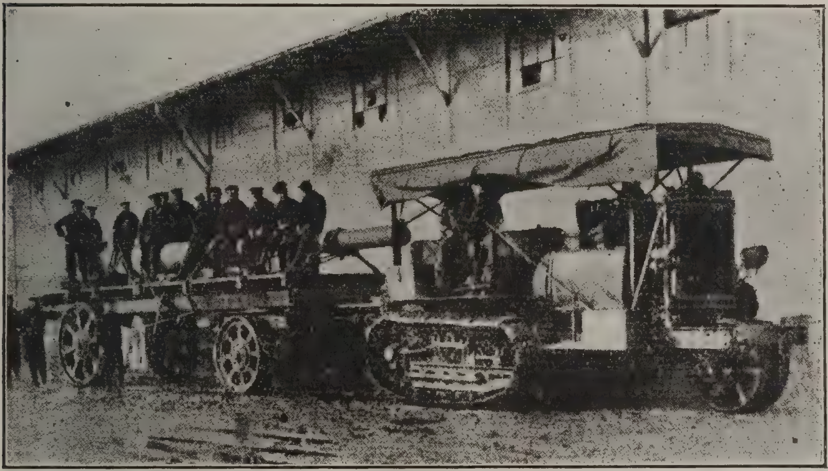

Fig. 3.

ground which would in many instances be impracticable for animals.

In general, this kind of traction is considered to be more expeditious, safe, efficient, and economical than that by team. It looks, therefore, as if it was going to be the artillery horse of the future.

TACTICAL EMPLOYMENT OF ARTILLERY.

The great power of the pieces which are employed to-day, the mobility that the mechanical tractor imparts to them, and the stationary character of the struggle in the field, a circumstance which assists materially in securing accuracy of aim, are the reasons that the artillery plays such an important part, especially as it can count on adequate observations of the objects chosen for attack. If it is field artillery, it is employed to cooperate with the infantry as necessity may demand. The guns of medium and heavy caliber, are used to oppose an assault when circumstances permit, to de-

molish earthworks, shelters and communicating trenches, as well as to destroy the woods, villages, groups of buildings, etc., that may serve as points of support for the lines of the enemy, or to conceal the emplacement of their guns and batteries, to respond to the enemy's fire, and to ruin the roads in the rear with a view of blocking the immense traffic which an action renders necessary, to sweep the aviation grounds that may be within range, and finally to throw projectiles of great size at irregular and unexpected intervals into towns and settlements that are being used as headquarters stations, or for the cantonment of troops, and force them to bivouac; for the great camps, such as used to be established, can no longer subsist within range of these guns, as they are constantly

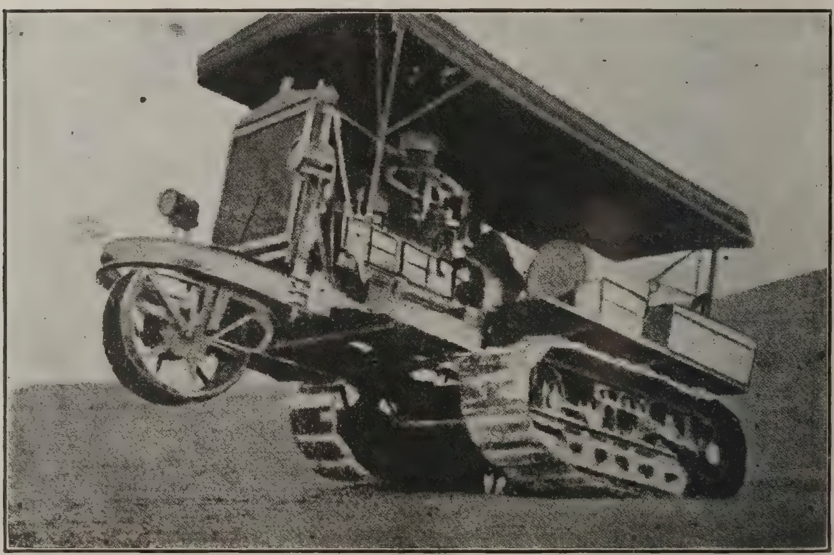

Fig. 4.

threatened with the danger of being located by aerial observers.

In one of the cities we were visiting, situated some 8 kilometers to the rear of the lines, there fell one night a projectile of 15 inches, wrecking three houses, which had been fired from a point 28 to 30 kilometers away.

The bombardment of trenches and of the neutral zone assumes on occasion proportions never before deemed possible. There are sectors where the cavities formed by projectiles coalesce in dense groups, their surfaces, tangent externally or internally, concentric or overlapping (see Fig. 5).

In the attack on the forest of Delville, to the east of Longueval, there fell to every yard (.914 m.) of front three projectiles a minute along a stretch of less than a kilometer. And the Germans, as has been reported, launched 100,000 projectiles in the course of

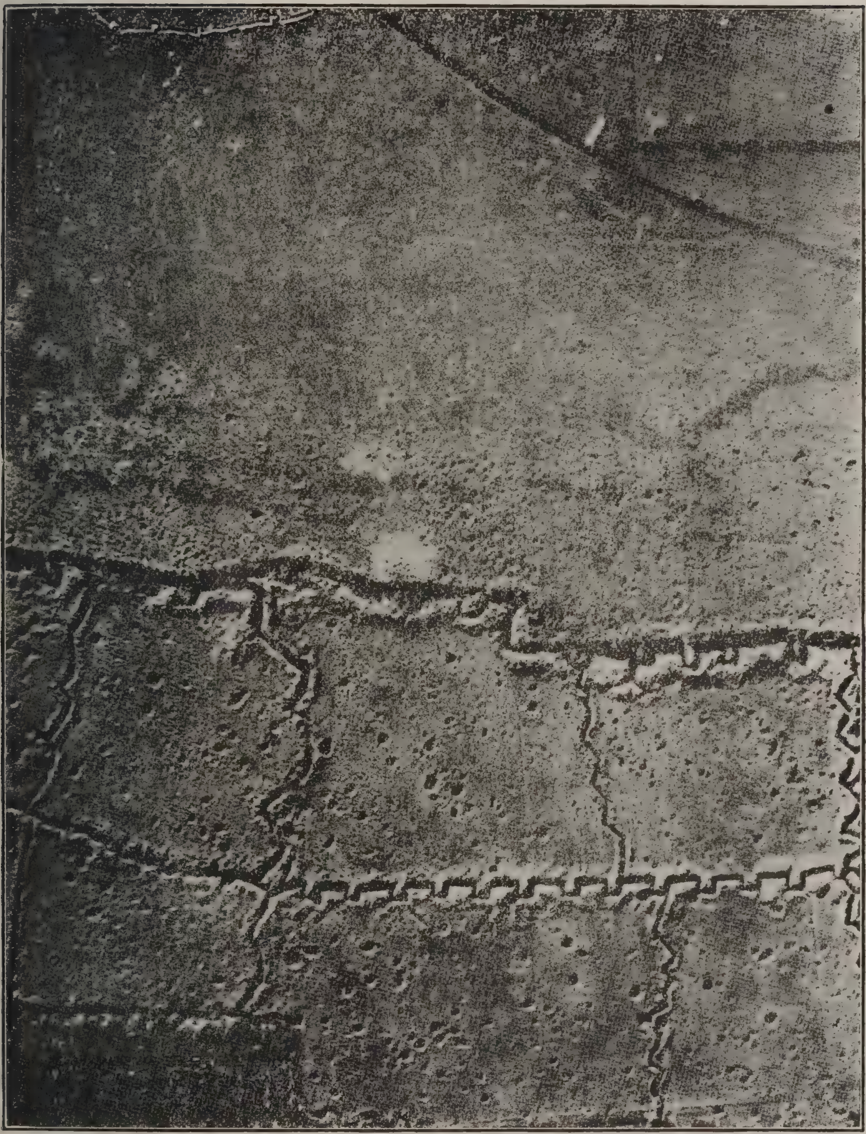

Fig. 5.

Fig. 6.

24 hours against a front of 8 kilometers, that is to say, 12 projectiles for every meter of front, and about 70 a minute during the time stated.

The weight of these projectiles represents a million and a half kilograms, and would need for their conveyance a hundred freight cars, or thirteen hundred 6-mule-team army wagons, while their cost would amount to more than three million francs.

Frequently, the two fronts are enveloped in a cloud of dust and smoke from two to three hundred meters in depth.

An illustration of all this may be seen in some of the pictures or sketches accompanying this article, and they resemble those photographs of portions of the moon's surface which exhibit the extinct volcanoes of that planet (satellite).

As to the material destruction effected by the artillery, it is sufficient to examine in Fig. 6 the appearance of the trenches subjected to their fire. We have witnessed explosions of projectiles discharged into forests, where the débris would be hurled to a height two and a half times that of the largest trees. All of the places once inhabited, which are mentioned in official reports, are to a great degree like those represented in the illustrations.

It is to be noted that the greater portion of the projectiles fired by the howitzers and guns of large caliber are filled with powerful explosives, and some are provided with time-fuses, and their destructive effects are truly horrible. The craters made by the 30.5 howitzer, as employed by the Germans, are some 9 meters in diameter and 6 meters in depth; while those made by guns of medium caliber are about 4 meters in diameter and 2 meters in depth.

So when the trenches of two contending forces are very close together, it becomes difficult to distinguish the lines as they were before the bombardment began, so great is the havoc wrought by the shells. In Fricourt, a town on the Somme, we have seen the ruins of trenches, showing a confusion indescribable, earth-sacks scattered in every direction, and all traces of the works as originally constructed effaced.

And that one can realize the demoralization which ensues from the fire of these heavy pieces, it is only necessary to point out that when the projectiles strike in the midst of a group of men the trenches are filled with the dead, many of them horribly mutilated, their clothing torn to rags, while sometimes their bodies are hurled clear out of the trenches.

The effects of concussion are also terrible. The tremendous displacement of air caused by the explosion of the shells occasions serious injuries to the lungs of the men who are in the vicinity, and in many instances even instantaneous death; men being found dead in the trenches standing or sitting in the most natural attitudes, with no lesions upon them.

And this does not take into account the men who become blinded, or are made deaf, or afflicted with nervous prostration, or

are driven mad. The hospitals are full of such. The accidents following concussion are a necessary consequence of the large calibers, and, like the guns themselves, they are an entirely new feature in war.

EMPLACEMENT OF THE GUNS.

Field artillery is ordinarily emplaced about a kilometer, or a kilometer and a half, to the rear of the first line of trenches. The medium and heavy artillery seem as if they were set in a bowling-green in a zone some 6 kilometers, or thereabout, back of the trenches. These are scattered about, always in well covered positions, and singly or two at the most in one place, so as to be as well sheltered as possible from the heavy artillery of the enemy, as also from aerial observation, which menace is always threatening. It is no uncommon thing to find cannon emplaced in the streets of a town, in a garden, or in the heart of a forest, the trees that might obstruct their range being felled.

The controversies maintained before the war concerning the masking of field batteries always hung on the well-known proposition that artillery must be placed so as to command the view, and —if it were possible—so as not to be seen. But in the present struggle, in which distances are known with the greatest accuracy, and where the means of observation and the matériel permit the concentration of the fire of many guns upon one determinate object, a battery once discovered by the enemy (and their aeroplanes make frequent flights over the hostile zone) is surely doomed to destruction in very brief time.

The certainty of this has been so amply demonstrated that if an emplacement has been discovered and reached by the enemy's fire, those serving the gun or guns hasten at once to hide themselves in the shelters in the vicinity, and there patiently await the destruction of their plant. Only in case field artillery is supporting an infantry attack, where a rapid and continuous fire is called for, do the men continue to serve their pieces up to the moment of their destruction, leaving the exposed point only at the last extremity.

So much for the covers: let us now consider the peril that threatens from the air.

CONCEALMENT FROM AERIAL OBSERVATION.

The employment of the gasoline motor, the conquest of the air, and the advances that have been made in means of communication, have increased vastly the importance of the problem of concealment. The aeroplane has compelled troops to hide their batteries from observation from above, violating all the old principles and traditions of alignment and of regular intervals between the pieces, and compelling them to cover the wheels and all parts of their equipments that might shine and betray them. If the pieces are not concealed in excavations, then natural conditions are simulated. They are covered from above with branches and leaves; frequently by lattice work—as with the English—over

which is spread grass, leaves, pieces of canvas that are painted green, etc. Oftentimes the shelters are covered with hay, manure, etc.

On the approach of a hostile aeroplane near the emplacement of a heavy gun, of which there are so many in the rear of the lines, a sentinel stationed in some advantageous spot gives the alarm, and the crew hide in their shelters; for it is considered a better plan to seek cover and remain silent than to attempt to destroy the machine by firing at it.

In the same manner, when it is dawn or just peep of day, they look to see if any of the enemy's scouts are on the watch, and refrain from opening fire, lest the flash of the discharge reveal the emplacement of the pieces, or the heavy cloud of dust, which invariably follows the discharge of a heavy gun, to remedy which latter happening it has become customary to sprinkle the ground with water or saturate it with oil, or to cover it with a carpet of leafy branches.

METHODS OF OBSERVATION EMPLOYED BY MODERN ARTILLERY.

Before the war it was considered so impossible to make note of the effects of the fire beyond a range of five or six thousand meters that artillerists rarely fired at an object farther distant than 5 kilometers. It is evident, however, that with the increase of caliber the difficulties of observation diminish, and that the explosions of the projectiles, being more violent, aid in a more extended reach of view.

It became then but a question of perfecting the methods of observation, as has been done on both sides, by sending far to the front officers entrusted with this duty, these being provided with telephones and good binoculars: also by having recourse to aerial observation, for which purpose the aeroplane and the captive balloon are so effective. The old time ladder observations and methods of that kind have long since been abandoned.

OBSERVATION OFFICER.

The observation officer is ordinarily a subaltern who, accompanied by one or two telephonists with a spool of wire, and a portable telephone in a leather case hung on the back, advances to the first line of trenches, if the field artillery is in action, or to dominating points existing in their vicinity. They connect their apparatus with the telephone lines already extending along the walls of the trenches of communication, and from their post of observation the officer reports the damage inflicted in the neutral zone, and watches the incidents of the fight, paying no attention to the individual noises incident to the struggle, these being lost and drowned in the thunder of the general engagement.

Following the vicissitudes of the strife, and in constant peril, he communicates through the telephone operator with the battery.

advising it of the proper moment for getting in its work, what kind of shot to use, giving corrections where called for, notifying it of occasions when the intensity should vary, or when to cease firing. In a word, he represents for the infantry the only guarantee which they can have, that the cooperation of the artillery will be exact, efficacious, and to be relied on. It may well be imagined, then, what an immense responsibility rests upon the shoulders of this officer.

The batteries of medium caliber also employ this method of observation, sending an officer about 6 kilometers away from the emplacement; but the observations follow the rule observed with the fire of pieces of greatest caliber, which is directed from above.

AERIAL OBSERVATION.

This is of two kinds: by means of captive balloons, and by aeroplanes. The first system is employed generally for the local observation of well known objectives; while the aeroplane is used to discover the emplacements of the enemy's guns, by penetrating into their zone. The former serves for a methodical bombardment, while the other discovers targets for their counter-batteries by detecting the hiding places of the enemy's guns.

The model of captive balloon used by the English is the same as ours, the "*cometa*" or kite, familiar to us all; and they employ them to the best purpose. On the day of our arrival at the Somme front there were as many as 32 covering a stretch of 11 kilometers and hovering in the air at a height of from four to six hundred meters, being stationed at a prudent distance behind the lines, in order to render as difficult as possible their bombardment by the German artillery.

The results of their observations are communicated to the earth by telephone messages and by wireless, these being received by officers detailed for this purpose, who in their turn transmit them to the batteries by means of megaphones or other available means.

The power of observation from the captive balloons is so efficacious that when a hostile balloon is seen men are forbidden to mass in groups, for fear of a shell being dropped into their midst.

On a clear day the lines are revealed to them until they are lost on the horizon, and soon there is heard a consequent roar of artillery, as an answer and result of their observations.

The enemy most to be dreaded by these balloons is the incendiary arrow, which aeroplanes drop upon them from above, setting them on fire or threatening it, and so compelling them to descend. The allies are employing these arrows on a grand scale with such success that, while on their side there were the 32 already mentioned, only 4 remained to the Germans.

The French also, it seems, employ "*cometas*" for observation purposes. The model called by them "*cerf volant*" consists of a string of balloons which sustain the observer in a basket or boat-shaped contrivance suspended from them. In the boat is a tele-

graph equipment of wireless of short reach, by means of which they transmit their messages.

The employment of the aeroplane to observe artillery fire is only coincident with the beginning of the present war. Before this French artillerists were disposed to be very skeptical about the availability of flying machines for the correction of aim, or for discovering the batteries of the enemy. In fact, according to artillery regulations (75) such means should not be resorted to save as a last extremity.

But hard facts have served to correct theories; and to-day their aeroplanes fly over the territory occupied by the enemy; and whenever they discern an objective they send off smoke-producing rockets, which leave a wake visible for a considerable period as a signal for the artillery to open fire upon the spot beneath, the aeroplanes notifying them of the effect of their shots by a special code of signals previously agreed upon. Independently of these, the scout aeroplanes are usually provided with a very light wireless outfit, by which they can only despatch messages, as the reception of such is interfered with by the noise of the helix or propeller of the machine.

On one occasion a single aeroplane, during the same flight, was able by employing these contrivances to correct the fire of three separate batteries against as many objectives. And the 30.5 centimeter gun, which bombarded Dunkirk from Newport, was located by a French aeroplane, and by its aid was silenced by the batteries of the defence. To-day the use of aeroplanes has become so general, that they have even come to the point of specialization; and when a battery has become practically a fixture in the war of the trenches it tries to retain the same artillery aviators, so that they may become thoroughly familiar with the objectives in the zone assigned to the battery, and can keep them apprised of every change that may be made. As these observation aeroplanes are very lightly armed, they arrange to have them escorted by a fighting machine, which soars above them, ready to resist any attack made upon its convoy by hostile aeroplanes.

THE SEISMOGRAPH AS USED FOR OBSERVATION.

Another very ingenious device for locating the emplacement of the enemy's batteries, which has been one of the developments arising from the stationary character of the war in the West, is to place at various points special contrivances which, founded upon the principle of the seismograph, record the vibrations of the atmosphere produced by the passage of a projectile, and the terrestrial tremors caused by the recoil of the pieces (see Figs. 7 and 8), registering these on a kind of membrane, which in a graphic manner serves to indicate the caliber of the guns that have produced them, as well as their distance and direction.

The result is evident, that by the frequency and intensity of the curves which the needle of the indicator traces, it becomes possible

to distinguish, by comparison with other records previously obtained by experiments on pieces of various calibers fired at different distances, what kind of gun it is which is in action, etc.

It is to be noticed that in the diagrams that register the vibration of the air the curves are less abrupt, while those produced by earth tremors are more intense and pronounced.

In one of the sectors which we visited we had the opportunity to observe one of these membranes when the apparatus was in action, and there appeared registered above each tracing the figures which indicated the caliber of the guns producing the vibrations, as well as their distance.

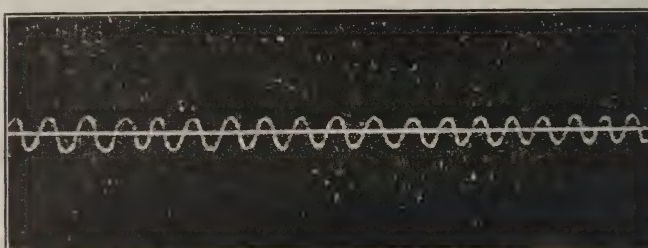

Fig. 7.

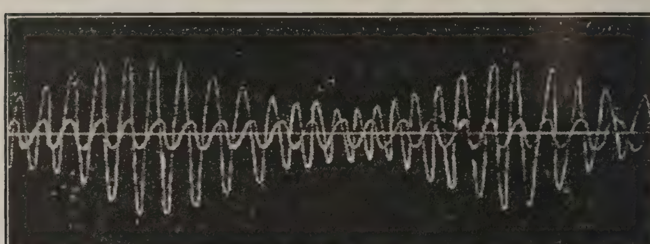

Fig. 8.

METHOD OF SUPPLYING AMMUNITION.

The gasoline motor, by furnishing mechanical means of transportation, has also revolutionized the business of ordnance supply, or the ammunition train service. Bombardments as occurring on either side in the present war would have been simply impossible if the ammunition had had to be drawn by teams. In this war the railroads bring up supplies to the advanced depots, and then the trucks assume the service of transportation, in many instances bringing the ammunition right up to the guns.

These trucks, at the present writing, can carry ten times more than they could at the first, and they can travel four times as fast.

The supplying of a battery of four pieces of 12 centimeter guns required before time the services of 70 horses and 30 conveyances. The same work is done to-day with only four trucks. In conse-

quence of this it happens, that while the park and ammunition column of an army division of a corps consisting of two divisions, the service being by animals, covered about 14 kilometers of country, now, with mechanical tractors, it extends only about 3 kilometers, about a fifth of what was once required.

With this powerful auxiliary the fire of the artillery may be made so intense that life over the field swept becomes impossible. And when at nightfall the artillery becomes silent, as observations then can not be made, the trucks return to the rear to replenish the waste of ammunition, so that by peep of dawn on the following day they are back again and supplying the guns. This means that mechanical transportation has come to resolve one of the most formidable propositions with which artillery had to contend heretofore, namely, the consumption and replenishment of ammunition.

If to this it be added that in the metropolis the English army is dependent upon some 4,000 factories and establishments in constant operation, to manufacture ammunition, with the industrial army that such service implies and that it employs 30,000 trucks along its front to tend to transportation from the rear, it may be understood how greatly the figures have been changed for supplying the pieces, as compared with those once considered indispensable.

The 2,500 projectiles, which the Germans, with their customary prevision, had deemed necessary for a light piece as a reserve supply, have now been raised to 5,000, a figure only limited by the estimated life of a cannon, until it is worn out by wear and tear.

One thing is sure, namely, that the favorable conditions which concur for carrying out in detail this service in the field of operations, of which we are now reporting, should not be taken as normal, seeing that the scene of strife is only at distance of two or three hours from the bases, that they have magnificent highways kept in first-class order, beside abundant railway facilities. But no matter what the conditions might be, it is certain that the artillery has found in mechanical traction a powerful ally, which enables it to face one of the gravest difficulties with which the serving of modern guns has had to contend.

CONCLUSIONS.

We, who were present at the very period of a radical transformation of the artillery service, which not even the most optimistic could have foreseen, a transformation affecting in greater or less degree every detail of its technique, we are justified in summing up the results in the following principal conclusions:

The mechanical deficiencies which some expected to find in the modern matériel, subjected as it had been to such severe tests, do not seem to have appeared. On the contrary, the hydraulic brakes and recuperators are not only found now in use with all field-pieces, but the prospect is that they will be employed on all new guns made, whatever their caliber may be.

The discrepancy that had heretofore existed between a gun's

power and its mobility has finally been obviated by mechanical traction, thus giving a promise of the employment of greater calibers in the future.

In coming times artillery will have a greater range even than it now has.

The utility and necessity of guns of great caliber, and with projectiles of high explosive power, have been demonstrated beyond cavil.

Pieces must be concealed, not only by vertical shelters but also from observation from above. The need for this is of immediate urgency.

The artillery command needs to be thoroughly instructed in directing its fire against objectives at long distances.

As the gasoline motor increases the mobility of guns of large caliber, and is able at the same time to furnish them with ammunition for a rapid and prolonged service of the pieces, and as such guns are most effective in an assault, the need is felt of a better cooperation of aeroplanes with the batteries. Units of these airships should be organized to be attached exclusively to the artillery; for domination upon the earth is necessarily conditioned by that of the air.

And, finally, while we may well understand that conditions in a war involving maneuvers might not be so favorable for the employment of artillery, as the one in which we have participated as observers, still we can not shut our eyes to the fact that heavy guns must play a preponderating part in the wars of the future, aided as they now are by the numerous adjuncts or auxiliaries which the progress of the times has evolved and put at their disposal.

INFANTRY.

In a war of the present character, where there is an extensive front occupied by the belligerents in a continuous line of trenches, where there are no flanks to give an opportunity for maneuvering, and where the elements of defence are innumerable, there is nothing left to do but to make frontal attacks anywhere along the entire stretch, attacks to be accomplished at the cost of a reckless expenditure of ammunition of all kinds and a lavish sacrifice of human life.

The main distance between the trenches of the opposing armies in the sections that we have visited varies from 50 to 100 meters. It is sufficient to give the artillery on both sides an opportunity to play. The English hide their guns back of the crests, covering themselves from the action of the heavy ordnance, while the narrow stretch between the trenches is just about large enough to give space for an infantry attack. The trenches are deep and narrow, about the width of a cot, as a precaution or protection against bombardment.

The main feature, then, of the combat is reduced to a charge across a narrow neutral zone, and the occupancy and retention of the enemy's trenches. Such, as a routine, is the rule; but the charge is made in the face of elements of destruction hitherto unimagined;

while the defence, knowing beforehand what point is to be attacked, has abundant time to make every preparation at leisure.

PREPARATION FOR THE ASSAULT.

Almost always, before an infantry attack, the artillery becomes very active. The medium and heavy guns fire hundreds of projectiles, mostly explosive, in order to demolish the trenches of the opposing side and to silence their artillery; while the aeroplanes overhead search for and signal the location of their shelters. The infantry in the meanwhile, seek cover from the enemy's fire in the dug-outs in the slopes of the trenches, some of them as much as 10 meters in depth.

This can not be considered as any too deep, when we consider the penetrating power of the projectiles discharged by the heavy guns. The maximum ordinate of the trajectory of a Skoda mortar of 30.5 centimeters is 3,984 meters, and the projectile has a weight of 379 kilograms. In another place were given the dimensions of the craters made by the explosion of these shells.

During lulls in the bombardment, as also in bad weather, when the guns are obliged to remain inactive, as observations are not then possible, the conflict resolves itself into trench warfare, and the employment of missiles thrown from one trench into that of the enemy. For such purpose are used mortaretes, aerial torpedoes, and hand grenades when the enemy's trench is near enough, also inflammable liquids, etc. Sniping is then in order, and rifles and machine-guns are fired against every one who ventures to expose himself above the parapet.

TRENCH MORTARETES.

These weapons, which are very much in use, are practically a revival of the siege instrument of mediaeval times. The model employed by the English consists, as a rule, of a cylinder of cast-iron strengthened with hoops or bands at the butt, mounted on a stout carriage which gives it an elevation of about 45°. The charge consists of little sacks of powder loaded by the muzzle, on which is placed, of course, the missile, which is just a can containing an explosive with fragments of metal and wadding, the explosion being caused by concussion.

The firing is done after the manner of blasting, by means of a fuse or slow-match long enough for the crew to seek cover, by which fire is communicated to the charge through a touch-hole in the breach.

The effects of the discharge are terriffic; and when the distance is only about 200 meters, and the aim has been accurately set, there is nothing to do but for every one to make for the caves. The havoc these missiles make in the trenches is very extensive.

The mine-thrower, the German "*Minenwerfer,*" is of wood strengthened with bands of iron, and throws a spherical projectile

a distance of 320 meters with an initial velocity of 60 meters per second only, so that those who see it coming have time to run to shelter. It is an arm of great precision and extremely destructive in its effects.

AERIAL TORPEDOES.

These are missiles charged with high explosives, also much used for demolishing the trenches during the preparations for an assault. Their destructive effects are also very great. If one falls in the vicinity of the shelters, and these are shallow, it tears them to pieces and closes them, interring the occupants, and paralyzing them by their frightful explosion, and the extraordinary confusion they create. In one of the trenches captured from the Germans at Fricourt, at the beginning of the battle of the Somme, the number that had fallen and taken effect was very great.

"PACO," "PAQUEO," OR "SNIPING" STATIONS.

The "sniping" stations are among the principal and characteristic features of trench warfare, as is natural when the trenches are within such close range of each other.

The best shots of the unit occupying a trench are stationed at embrasures or "*crenals*" (see "*creneau,*" Willcox) in positions carefully chosen, which command an ample field, with the purpose of annoying the enemy, firing against similar embrasures on the opposite side, at the doors and windows of ruinous edifices left standing in the rear of their lines and against any head or hand which may be exposed above the level of the trench. Some of these use guns with telescopic sights, and automatic rifles to assure themselves of their prey. This is a refinement in sharpshooting that gives excellent results. And so it happens that during the day—for fear of these (S)—the trenches give no signs of life, although they may be swarming with men. (See Fig. 9.)

When these sharpshooters are not firing, they are constantly watching the ground before them, examining with their glasses all such places as might serve for cover to a man, such as trees, clumps of bushes, a pile of hay, etc., or they are on the look-out for the flash of a discharge betraying the position of a "sniper" on the other side.

And so the rifle firing and the bombardment keep up for days and days, and whenever it is considered that the energies of the defense have been sufficiently exhausted, and the barbed-wire entanglements have been wrecked by the shells of the field artillery, whose missiles are usually employed for this purpose, the troops begin to form in the depths of the trenches in readiness for the subsequent effort, which is to be an assault.

ADVANCE OVER THE NEUTRAL ZONE.

This is the culminating moment of the battle. To arrive at it, there have been previous preparations, at times for months, which

have made heavy drafts upon the resources of the country, and demanded the services of thousands of men. And this moment, as is always the case, is that which is reserved for the infantryman; since he, and he alone, is the one who is capable of taking the front, aided, of course, by machine guns, rapid-fire guns, aeroplanes, etc.

Let us detail all of its phases as was related to me by a man who took part in one of these engagements.

The zone which was to be traversed to gain the enemy's trenches was scarcely 90 meters in breadth. At the moment determined upon, the men occupying the first line of trenches, leaped over the parapet, headed by an officer, and burst into the open, making their way through the winding paths of their own entanglements, to spread out in a rude skirmish line, which is the formation generally adopted for an assault.

Fig. 9.

At the same moment their own artillery, consisting of all of the pieces and calibers available, principally, however, of light field-guns, opened a furious fire upon the trenches of the enemy, who, on their part, received the assailants with a discharge of rifles, machine-guns, and cannon, mowing down hundreds of men before they could even thread their way through the entanglements.

In the midst of the confusion that this occasions some of the men start back for their trench, others lie on the ground behind the bodies of those who have fallen, or in the shell-made pits which are so numerous, while the balance continue to advance with bodies bent and heads inclined, as if they were fleeing before a tempest, seeking to reach the shelter of the first hole that may offer or that they can make, or to cast themselves to the earth should these fail them. The enemy pour projectiles like hail from their guns, and a

hurricane of balls from the rifles and machine guns is directed against the shelters improvised by their opponents. The bursting of the shrapnels tears great gaps in their ranks, until after 40 meters of advance, the assaulting line has been torn into fragments. The advance still continues, until at 50 meters the groups have been converted into clumps and isolated men, with enormous intervals between. When they have gained 10 meters more, there is only to be seen a man here and there; while at 70 meters from the point of starting, the primitive line has completely disappeared. Not a single man is left standing, while the fallen lie scattered over the ground, among whom the wounded are dragging themselves along, seeking some point of safety in the midst of the rain of shot and balls from the shrapnels that is pouring about them.

Finally their own artillery, sending a deluge of shells and shrapnels against the enemy's trenches, succeeds in silencing their rifle fire, which permits those to gain shelter who were crawling over the ground, and also the litter-men to sally forth and rescue some of the wounded.

Coincident with this momentary lull, there leap over the parapet a new wave of men, those who had been occupying the supporting line of trenches, and had moved up into the first line; and again the machine gun and rifle fire reopens from the enemy's side, which the opposing artillery endeavors to silence. In the meanwhile other forces have occupied the trenches of the first line, and by the time the other force has succeeded in covering half of the ground they are dashing out in the open and charging forward. And so only by wave after wave of advancing troops following on does the first contingent succeed in attaining the entanglements, seeking for available paths where the previous artillery fire has destroyed them, losing ever more and more men, but finally climbing the parapet and entering the trench.

Prior to this the artillery of the attacking columns has been directing its fire against the enemy's rear, in order to prevent their sending forward reinforcements through the rain of shrapnel and curtain of fire. And while a new swarm of men has started from the trenches, these finally succeed in occupying those of the enemy [that is, of the first line].

OCCUPATION OF THE CONQUERED TRENCHES.

The events described, which covered in fact only a few seconds, or at the most, minutes of time, hardly gave opportunity to the soldiers to use their rifles during the advance. His legs, his heart [courage], and the supporting fire of the artillery, were the means by which he finally won the trench. You can understand now how, in order to save lives, they may resort to mines, to asphyxiating gases, to smoke-engendering bombs as a means for blinding and paralyzing the enemy, and gaining their goal. Sometimes it is found that operations have to be suspended on account of the

mud, since every minute of delay in the advance, occasioned by such causes, signifies the sacrifice of hundreds of lives.

The operation of crossing the neutral zone takes place simultaneously at various points along the line, in every case the endeavor being made to retain what is conquered and to penetrate as much farther on as is possible, the struggle now entering upon a new phase, which is the permanent occupation of the trenches captured.

Now is the time for the hand grenade and for the bayonet. At the head of the assaulting troops go the grenadiers, who contribute largely in overpowering the defence by throwing these missiles. But, as it has never been possible to win the whole line of trenches, and spaces remain unoccupied by the assaulting columns, which can only be taken by desperate fighting inch by inch, the grenadiers hurl their bombs into them, suffering at the same time from the fire of grenades thrown into their midst by an enemy resorting to the same method of defence.

After the first line of trenches has been thus occupied, and after a hand-to-hand struggle with its defenders, before the advance can proceed further the assailants recognize the caves and dugouts along the slopes, where many of the enemy have taken shelter, barricading themselves with sacks of earth and boards, which have to be cleared out, the assailants facing a sharp rifle fire from the loopholes, and seeking somehow to cast their grenades among the defenders; and all this in the midst of a continuous fire of explosive shells and shrapnels.

The trench having finally been cleared of the enemy, then a way has to be beaten out through the communicating trenches to the second line, every step being contested and the fighting being with grenades and the bayonet, until finally the last man has been destroyed or placed *hors de combat.*

COUNTER-ATTACK.

In general, when this stage has been reached of the combat, there comes a counter-attack by the enemy. Troops sally forth from the next immediate trench, which is situated some 20 or 25 meters beyond and, rushing over the narrow space between, endeavor to reconquer the trench that has been captured. But as such a counter-attack is always to be expected, they are received by an artillery fire which decimates them. At the same time there will have been arrayed with all despatch along the parapet of the captured trench a line of marksmen, who open fire on those attempting the counter-attack, throwing them into confusion before they can well organize their ranks in form. A second attempt is made before the defenders may have had time to recharge their pieces; but they are usually met with a sharp fusilade and with artillery fire and grenades. Then at a word of command, those who were on the defensive suddenly assume the offensive charging

the enemy with the bayonet, thus reaching the second line of intrenchments, where the same story is repeated.

In some instances this second line is taken with little difficulty; but at other points the defence is very stubborn and the fighting hand to hand. It not infrequently happens that while the first two lines of trenches have been occupied, the struggle will still be kept up in the communicating trenches by men who have become separated from and left behind by their comrades, without knowing the fate of the trench for whose possession they still continue to contend.

The arrival of reinforcements gives an impetus to the advance upon the third line, and in the same fashion they press on to the fourth and fifth lines if such there are. It often happens at this stage that a handful of assailants will find themselves in such a pass that they can neither advance nor retreat, their ammunition and hand grenades having become exhausted; and while they wait for succor, whose arrival is problematical, they are driven to using the rifles and bombs of the enemy lying dead in the trenches.

This failure of hand grenades constitutes one of the most serious and frequently recurring perils in the attack on trenches. The purveyors of this ammunition who follow the assaulting columns have to make a veritable and dangerous pilgrimage in order to reach their destination, beset with all kinds of difficulties; having to traverse the neutral zone, the first line of trenches completely dismantled the communicating trench, the second line, the third, etc.; and all this climbing over the bodies of the dead and wounded, exposed to the bursting of explosive shells, and having to cross a barrier of iron created by the fire of the enemy's artillery, which does its best to oppose such progress.

After leaving the third trench, the advance becomes increasingly more and more difficult, inasmuch as the enemy can count on a more abundant supply of cartridges and grenades, and because his communications are easier and more abundant between the lines of entrenchment, there being a lesser distance between them, so that they can more easily ply the oncoming troops with hand grenades from under safe cover.

These things generally cause the attack to come to a halt at such a point; and as the second line has been occupied, they set to work to put it in shape as a new front, awaiting the arrival of fresh reinforcements, which ordinarily reach them on the following day after a night of incessant struggle for retention of the trenches they have conquered.

For this purpose, as soon as the success of the attack has been assured, men come to the aid of the assailing forces, carrying loaded sacks of earth upon their shoulders, with which they construct a parapet; while others, provided with rolls of barbed wire, stakes and mallets, hastily construct entanglements on the ground beyond.

On the following day the reinforcements that have assembled during the night, while the engineers have been engaged in estab-

lishing trenches of communication across the neutral zone, proceed to follow up the attack, repeating the operations as already narrated. Naturally, this work of the engineers is hampered by the enemy in every way possible. They illuminate the neutral zone with light-creating projectiles, which serve for a period of from 5 to 40 seconds, without casting shadows, and exposing the position of the men working, thus confusing their operation.

They also employ rockets discharged from pistols, which illuminate a space of some 200 meters for a period of 20 seconds. When these are set off the men at work have nothing to do but to cast themselves to the earth, and lie motionless among the bodies of the slain until the radiance has ceased.

HAND GRENADES.

One very important point is to be dwelt upon, and that is the value of the part which the hand grenade has assumed in this war. It has come to be an arm of the infantry just as much as the rifle and bayonet. It constitutes a weapon of defence, as a barrier to any attempt of the enemy against the trenches; and in the attack it is equally efficacious in forcing them to abandon their positions. It has come to be a substitute for field artillery when that is compelled to remain silent on account of the close contiguity of the combatant forces. For driving the enemy out of his trench, and to cover an assault in heavy column, it proves to be superior to the rifle. For this reason they have now large supplies of these missiles stored in the trenches, the number footing up to as many as six thousand for a battalion.

NIGHT ATTACKS.

Another subject that requires our attention in considering this kind of warfare is that of night attacks. As is well known, when the circumstances are exceptional, they are very effectual where by creeping up on the enemy the distance still to be won may be diminished; for the obscurity serves to lessen the effectiveness of the enemy's fire at moderate distances, and at considerable distances still more so, reducing the danger zone to much smaller dimensions, even less than that of former times in engagements by daylight with the armament of, say, a century ago.

But now, with trenches hardly a hundred meters apart, and with cannon and machine guns in ambush trained to pour a stream of fire from their covers over the ground just the same as in the daytime, it must be conceded that the advantages from the lack of light are much less in the present; and, besides this, there is always the risk of shelling one's own troops, with all the demoralization which must necessarily follow such an unfortunate occurrence.

MACHINE GUNS.

The employment of these weapons deserves a section by itself. From all the observations made it is incontestably evident that they

are the best reliance for defence. The havoc they create is so great that the entire character of modern warfare has been modified by their employment. Along with the artillery, they are the most demoralizing instruments of destruction that can be used. And as compared with the cannon, the proportion of losses inflicted by them is about 90 per cent.

It is by all odds *the* arm for destruction and for defence. Its special sphere is in sweeping over the ground at short distances, a condition characteristic of this war. And it is the most effective arm for resisting night attacks, as it can cover the entire ground over which the enemy is trying to force his way.

The proportion of these guns now in use is incomparably greater than was ever dreamed of before the war, their number being difficult to ascertain. We have been assured, however, that there is a machine gun for every 25 meters along the western front. We may with certainty affirm that the English have them in every available position along the Somme front, with cross fires, and masked within shelters especially constructed for the purpose, and that independent units provided with these weapons have been organized on pretty much the same lines as field artillery; thus putting to rout all the old ideas that were at one time entertained as to the employment of this arm, when it used to be deemed impracticable to mass them, or to supply them in numbers sufficient for an adequate offensive.

Independently of the regulation models as authorized for the English army, a new gun having extraordinary advantages has been adopted, the Lewis rapid-fire gun, a gun of North American origin [United States], but manufactured now in England. Its weight is only eleven and a half kilograms, so that it can be handled almost as easily as a rifle. It requires no carriage, as do the other models, the tripod upon which it sets being carried with the piece; and it is able to fire from six to seven hundred shots a minute from the moment that the first cartridge is exploded.

The gases created by the combustion of the powder are not only used to work the mechanism, but are also available for preventing the temperature of the gun rising higher than from 350° to 400° Fahrenheit (165° to 220° Centigrade).

The refrigeration is effected by the use of a detachable jacket made of aluminum, which surrounds the barrel, and is provided with fans which create a current of air, the same being operated by means of the gases evolved.

Instead of a feeding-belt, as is the case with other forms, it has a disk with 50 cartridges set in the radii, working on a vertical pivot at the breach, around which it revolves automatically after the first shot. The operation of changing this feeder is effected in only two seconds.

Troops on the march transport this gun in a two-wheeled handcart of very simple construction, the equipment of the crew being also carried upon it.

This new machine is used not only in the trenches, but also, as its weight is so slight, on aeroplanes, for firing against those of the enemy. They are fitted with sights arranged specially for such service, and they can be fired in every direction, from the horizontal to the vertical.

THE TECHNIQUE OF INFANTRY AND THE STRUGGLE IN THE WEST.

As is well understood, the strength of infantry lies in its firing capacity and in its power of shock. As to the former, it serves as a means for approaching the enemy, and then to finish him by a hand-to-hand struggle. We are obliged to confess that in this war of trenches infantry fire has lost ground. On the other hand, the shock has advanced considerably in importance, giving this arm [infantry] a greater preponderance even than it ever possessed before. If it has lost in one direction, it has gained in another. Let us enlarge on this theme.

Formerly, in battle in the open the advance of infantry was opposed by heavy artillery from a distance of 9 kilometers, at from 5,000 to 2,000 meters it was swept by the fire of field artillery, and when the attack had arrived to within 500 meters of the enemy the rifle and machine gun began to get in their work.

And yet, despite all this, there was a chance to evade or minimize the peril, being under the cover of their own artillery, taking advantage of every inequality the field offered to shield themselves, trusting to errors in aim and computing distances on the other side, and their shot going wild. But to-day it happens that all this fire, which formerly was distributed over such an extensive zone, is now accumulated, multiplied a hundred-fold over a narrow belt, sometimes not exceeding more than 30 or 40 meters in width; and so the consequence is that not a hand-breadth of ground remains untouched; and all this without the infantry being able to respond, save only to a limited extent, with their proper weapons.

Then let it be taken into consideration that while a battalion, at critical moments, may fire a determinate number of bullets, in the same space of time a battery will discharge twice as many balls without being seen, or at the worst with only a slight degree of exposure.

So they are obliged, if they wish to advance, to rely on the cannon as an auxiliary. And for this purpose the artillery places at their disposal as many pieces as it possibly can, even, if the need be imperative, to the extent of crippling themselves.

And that this assistance is more necessary to-day than ever before is shown by the fact, that whereas the artillery used to support the infantry only to within 500 meters of the enemy's lines, now, as with the English, they do not let up their fire until that arm is only about 90 meters away, with all the risk that such proximity would suggest to the officer on observation.

A very little reflection over this change in tactics must convince one of the difficulties with which the infantry have to contend in a

charge. Man can not fight alone against material elements. The material must perforce be opposed by cannon.

The cannon, then, is to the infantry what the starting crank is to the gasoline motor. Without it he could never initiate the movements that lead up to their climax, namely, the shock.

On the other hand, when the culminating point of the engagement, which is the shock, collision, or charge, has been reached, the infantryman must then exhibit all the virtues of a stoic, being insensible alike to fear or pity. Recalling the picture of the assault as depicted by us, it is to be seen that the cannon, hitherto so dominating, has now, despite its effectiveness, no part to play in the final and decisive act, without which victory would be an impossibility. Its very character compels it to silence now that the men are brought face to face and hand to hand. It is for the foot soldier now to do the rest. And this, in comparison with the character of strife in other days, makes the part of the infantryman truly gigantic; for then they had not thrown into the game, as they have to-day, elements of destructiveness most of whose power and effectiveness no human being could have forecast.

The infantry is now confined to a frontal attack, the most difficult of all methods known; and there is nothing for him to do but to pound steadily forward over a path swept by an iron tempest, to spread out his lines, and to increase his depth, so as to overcome the peril by a continuous stream of new men coming up. And the day in which the losses of effectives shall be known in detail will reveal how the machine, to punish him for having had the audacity to make front against it, has decimated his ranks without mercy, so great has been the slaughter inflicted upon the infantry by the fire of artillery of every kind and description. After an engagement it is no uncommon thing to find companies commanded by corporals, and battalions, whose effective strength has been reduced to that of a company, commanded by captains or lieutenants. These things speak for themselves.

And more than this: the physical and moral drafts made upon the infantry by the incessant character of their labor mean so much. For the strain continues day and night, the being under fire for hours and days at a time, the lack of rest, the broken sleep, the constant state of tension and apprehension, and the corporal lassitude that all of these produce serve to affect the morale more than their actual losses and casualties. To mitigate this stress as much as possible taxes all of the energies of the commander, endeavoring as he does to secure adequate relaxation for his men in proportion to their powers of endurance, for the raw recruit or for the seasoned veteran, as the case may be.

And if this is the situation created by the material elements which the progress of the times has introduced into warfare, in what way will they go about to win the victory? As we examine the question dispassionately, there seems to be no other way than to rely upon the moral strength of the men, to make them insensible to

the dangers that beset them. It is a sure thing that whichever side first loses its grip is beaten. The cannon labors to-day mostly with this end in view, to demoralize the enemy. It behooves the commanders, then, to do everything in their power to mitigate this danger.

The English give much attention to the instruction of the men as individuals, training them to be dexterous in finding or making cover, in bayonet exercise, in marksmanship, and in general to be self-reliant, so that they may have thorough confidence in themselves; seeing that the chances are that each must fight out in many instances the battle for himself, without that touch of shoulder which so stays a man, with nothing more than the example of his officer, who is always the first to sacrifice himself.

(*To be continued in No. 47.*)

The Influence of the European War Upon the Art of Field Fortifications.[1]

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Fortification may be defined as the art of modifying and supplementing terrain by all available means, in order that one's own military forces may occupy a position in spite of the efforts of the enemy to dislodge them. If the positions are intended to be held only temporarily, and are executed either in the presence of the enemy or in anticipation of his immediate approach, the works are called *Field Fortifications.*

The considerations which lead to the occupation of a position are many and varied, usually depending upon the strategical or tactical situation, and will not be discussed in this article; but the *general principles* which govern the fortification of that position after it has been decided to occupy it are always the same, and may be stated as follows:

> *1st:* Provide for the most effective use of your own personnel and weapons.
>
> *2nd:* Restrict the effective use of the enemy's personnel and weapons.

The *five objects* to be sought in any field fortification conforming to these principles may be briefly stated as follows:

- (*a*) Provide *Observation* for effective fire on the enemy;
- (*b*) Provide *Cover* from the enemy's fire;
- (*c*) Provide *Concealment* from the enemy's view;
- (*d*) Provide *Communication* for one's own troops;
- (*e*) Provide *Obstructions* for the enemy's troops.

The two general principles given above are from their nature unchanging; and the five objects to be sought in applying these

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[1]Compiled from official and other sources.

principles are also very seldom altered; but as new equipment and new weapons are introduced in warfare, we find the *relative importance* of these objects subject to change, and the *methods* pursued in attaining them constantly varying to suit the new conditions imposed by the new equipment or weapon.

The principal changes in equipment and weapons which have occurred during the past three years of war in Europe are:

1st: Increased caliber and range of modern mobile artillery.

2nd: Enormous ammunition supply for artillery made possible by organization of factories in the rear of the army, and rail and motor transportation to the front, thus warranting unprecedented expenditure of ammunition.

3rd: Introduction of equipment for successfully navigating the air, thus providing information as to location of concealed targets, and accurate control of artillery fire on them.

4th: Increase in number of machine guns supplied.

5th: Introduction of grenades and high explosive bombs, either thrown by hand, from the rifle, or by means of special apparatus.

6th: Introduction of use of poison gas, liquid fire, and suffocating, tear-producing and smoke-producing gases.

7th: Introduction of armored motor-cars and caterpillar-tractors similar to the British "tanks."

The influence on the design of field fortifications of the first four of the above changes is very noticeable in all reports from Europe; while the last three changes, although more radical, have apparently had little if any effect, possibly due to their comparatively recent introduction and restricted use (so far, mainly on the Western front). However, one report indicates that the successful use of armored automobiles for attacking trenches has led to the introduction of mountain guns (2″ calibre) into the first-line trenches, which is undoubtedly a radical departure from previous accepted practice.

It is proposed in the following pages to investigate the experience with field fortifications in the European War with frequent quotations from those who have had an opportunity to draw conclusions from experience in Europe, with a view of determining whether or not previously accepted standards of design should be modified in the light of that experience, and if so modified, to determine, if possible, the nature of these modifications. It is realized that the real lessons of the war will not be available until its

conclusion and the official reports and accounts of those engaged on both sides are available for careful study; but it is believed that a preliminary study of the experience to date will be of considerable value.

All of the quotations given herein represent the opinions or experience of trained men, and are not quoted from newspapers, magazines, or periodicals.[1]

For convenience in discussing the subject, it will be arranged under the following headings:

I. General considerations;
II. Firing trenches;
III. Communications;
IV. Overhead cover;
V. Obstacles;
VI. Machine guns;
VII. Artillery;
VIII. Observation;
IX. Miscellaneous requirements;
X. Conclusions.

I. GENERAL CONSIDERATIONS.

(*a*) It is believed that the first and most noticeable lesson to be drawn from the experience in the European War to date is *the importance which should be attached to the study and knowledge of field fortifications by all combat troops, and especially by their officers.* The necessity for this knowledge of field fortifications by all line officers is apparent, not only from the wide use of field fortifications on the Western Front, where the popularly termed "position warfare" is only the extensive use by both armies of well-known principles of field fortification applied to a long and stubbornly contested front; but also from the fact that on every front in Europe, and in every campaign, no matter how rapid the maneuvers have been, reports indicate that field fortifications have played a most prominent part. In most cases their design and construction could not wait for the few engineer officers available, but were undertaken at once by the fighting troops themselves and under the supervision of their own officers.

Extracts similar to the following from all fronts might be multi-

[1]For the sake of uniformity all dimensions or weights not expressed in standard units in common use in the United States have been reduced to those units; for example, kilometers to miles, meters to yards or feet, centimeters or millimeters to inches and kilograms to pounds.

plied almost indefinitely to show the necessity of a thorough knowledge of field fortifications:

Use of trenches so general that one might say the troops are always in trenches. Entrenching is automatic upon halting for the night, or halting for any reason under fire, whether attacking or not.

. . . .

As a rule, trenches develop from the line of individual pits dug by the skirmishers to protect themselves.

The attacking forces built trenches when forced to halt.

The general tactics of both armies seemed to be a combination of offensive and defensive. Every position was both defensive and offensive, and this is the cause for the large general use of the wire entanglements, even on the offensive. No one knew when an offensive position might change to a defensive one, or vice versa. On the offensive it was seldom that a successful assault could be made over more than a few hundred yards, and then not unless it had been prepared by a very effective artillery fire. To attain a position from which an assault could be made with some degree of certainty, it became necessary to do as much advancing by night as possible, and then, by slow stages of entrenching, to approach within hitting distance of the enemy. A method of approaching used by both armies, I am told, is interesting. I saw this being done by one of the belligerents, and it was explained to me as follows: The attacking force takes up a position as close to the enemy as they can, with safety, and entrench securely. This would probably be done at night. This position is the base from which the attack is to be made. As they themselves may be attacked, this is really constructed as a defensive position for the time being. This position is protected by wire entanglement, portable, or portable and permanent. The portable entanglements are a type of "chevaux de frise," made of wood and wire, about 12 feet long, and easily carried by two men to a section. These are put end to end, lashed together, and form a continuous line. This line of wire entanglement, the portable one, is on the outside of any other wire which may be used. To guard against surprise at night each side has "outposts" of a few men between the lines. Having completed the first position satisfactorily, the advance is made as follows: All along the line individual men are sent out just before daylight a certain distance to the front, say 200 yards. Probably at first only 4 or 5 to a company are sent out. Each of these dig a trench at once for his protecion, and then works throughout the day digging this trench, and extending it towards that of his neighbor. At night they withdraw behind the first position. The following morning, say, two men are sent out for each hole already dug, and they continue the work through the day, withdrawing at night, and so on. When this new trench is completed, the whole line moves under cover of darkness, carrying their portable wire entanglements, and occupy this new line. Connecting trenches are dug between the first and second line for communication and supply. (1916.)

Attacks are now undertaken, at least on the east front, not by three to ten successive lines, but by single men going forward, under cover of a heavy fire, to designated points where they dig themselves in. Later, more men advance singly to unoccupied points of the new line. In this way a trench closer to the enemy is gradually built up. This procedure is repeated until the attack has reached a position so close to that of the enemy that a final assault "en masse," if necessary at night, is possible. This method of attack saves at least fifty per cent of the men who would have fallen in the attack formations used at the beginning of the war. (1916.)

While the infantry was very well equipped with entrenching tools at the beginning of the war, many of the regiments have increased this equipment. Whether this has been general or not, I do not know, but the pick and shovel (particularly the shovel), are, next to the rifle, the most important of all the equipment. I have seen infantry soldiers carrying the long-handled shovels of the sappers, which they had picked up somewhere, and which they were perfectly willing to carry for the increased efficiency of this tool. (1916.)

Our present "Manual of Field Service Regulations" (1914) contains only a small amount of matter on the subject of Field Fortifications. It is believed that either a considerable portion of these Regulations (at least 50 pages) should be devoted to this important subject, or else a handy pocket manual of field fortifications should be made available for the use of our line officers. There should be incorporated in this manual, among other things, definite instructions about normal types of the common forms of field fortifications, including at least the following: a *normal firing trench* showing the progressive steps in altering the individual skirmisher's shelter through the various intermediate types to the complete trench, these changes to be made successively, rapidly, and without any modification in the organization of the working parties; also, a *normal communication trench*, a *normal machine-gun emplacement, a normal light shelter* (proof against 3-inch gun or less), a *normal cave shelter* (proof against the heaviest modern mobile artillery), and a *normal wire entanglement;* also methods of modifying these normal types to suit varying conditions of terrain; and *every line officer should be as familiar with these types, and methods of constructing them, as he is with the drill regulations of his own arm.*

In this connection, the following quotation from a recent lecture on field fortifications at a training school for officers of one of the belligerents is of interest:

Although officers are authorized to modify the regulations, it is, however, essential to teach the infantryman to execute automatically a single

type. Experience has shown, moreover, that it is necessary to establish fundamental dimensions which are the best; they must be known by heart, and on the ground carried out to within 2 inches by the N. C. O.'s, who will be supplied with wooden measures. (1917.)

(*b*) The European War has furnished ample opportunity to try out existing theories as to the proper *general organization and development of a defensive position.* Some of the different systems advocated prior to the war are:

(1) The "Single Line" system of the German Regulations for Field Fortifications (1906), with very little mention of "Supporting Points"; condemnation of "Advanced Positions"; and reliance placed on a single line which is strengthened by all possible means.

(2) The "Multiple Line" system of the French, which lays great stress on the importance of "Advanced Works," and the construction, usually, of two or three lines of defense, one behind the other.

(3) The "Discontinuous" system, in which the main reliance is placed on "Supporting Points," with intervals of 800 to 1,000 yards, each interval protected only by flank fire from the "Supporting Point," which may be either a series of detached trenches prepared for fire to the front and flanks, or may be in the form of a continuous "ring trench" prepared for all-around defense with a surrounding obstacle.

(4) The "Continuous Line" system, in which all parts of the line are equally strong, and no provision is made for all-around defense of any portion.

It is interesting to note the experience with each of the above systems in Europe during the past three years of war.

A communicating trench with a firing crest, protected with barbed wire entanglements, should connect the centers of resistance, thus forming a continuous line of trenches, and preventing the enemy penetrating between the strong points. (1917.)

They consist of a series of short detached rifle trenches with variable intervals; each trench sector has a capacity for 40 to 80 rifles.

Advance positions were used when the topography demanded. Closed works or even semi-enclosed works were rarely if ever seen. Even detached positions were not closed to the rear. Valleys were crossed by bringing the trenches back on the hill-sides sufficiently to give thorough flanking. The ends used were then joined by a trench. (1915.)

In rear of the main fire trench, which is continuous, are second and third lines of trenches at distances of several hundred meters, all having

their wire entanglements. Rear lines are not continuous, but are laid out so as to effectually cover the foreground and to afford mutual support.

The second line trenches are a repetition of the first line, but not so carefully completed. About 300 yards separates the first and second line trenches. Every 1,000 yards or so along the line, and about 100 yards in front of the second line trench are what are called strong points. These are small and very strong redoubts, plentifully supplied with machine-gun emplacements, and of profile similar to the firing trenches. (1917.)

The lines of the enemy were divided into sections, each one of which was enclosed as it were by lateral and transverse trenches.

During a night attack when our soldiers, with admirable impetuosity, penetrated the hostile lines, the enemy gave way; but instead of running to the rear, where they would risk coming under the fire of their own machine guns, they moved quickly to the right and left into their lateral trenches. There they waited till our assaulting columns exposed their flanks, when a murderous cross-fire decimated our troops.

Another method consists in locating the trenches in such a manner that each line is shorter than the one in front of it. Thus they obtain a series of triangles one behind the other, the bases turned toward us. The vacant spaces between these triangles form in their turn a series of triangles turned in the opposite direction. Here is what happens in consequence: When, in the course of a bayonet charge, certain of our units find themselves brought up against well placed obstacles, there are, on the other hand, other units which find in front of them only open spaces; carried away by their enthusiasm, the latter troops press forward and get far ahead of the neighboring columns; the attack thus becomes divided, broken into zigzags, and our soldiers soon become scattered and confused as if in a system of cunningly spread nets. But this is not all. Behind the open spaces the enemy places machine guns. When our attacking troops come into the open and find no obstacles in front of them, they stop through indecision, fearing a trap; the machine guns then open a terrible fire on the masses of men. (1915.)

Point d'appui is unpopular, being most subject to attack. Straight trenches are preferred, as flanking fire is not to be relied upon.

Have as much frontal fire as possible, as it has been found that during an attack by the enemy, which usually occurs at frequent intervals during the night, and is generally universal along the whole line, each section can give but small assistance by flank fire to the section on either side.

In the event of the flank or flanks of a defensive line having to be drawn back, the trenches should be constructed in echelon. Curved trenches are subject to enfilade fire, especially by heavy artillery at long ranges.

The Firing Trench is only 18 inches wide, with no head cover, as owing to the proximity of the enemy's trenches, head cover prevents sufficiently quick resistance to bayonet charges. The Firing Trench is recessed every five rifles, and is located on the reverse slope of a hill, if possible.

THE COMMUNICATING TRENCH contains the latrines.

The trench for the Supports is 16 feet deep and 2 feet wide, or as near as may be, and has recessed dressing stations and kitchens.

The following summary will give a good general idea of the means taken to prepare a defensive front in trench warfare:

(1) Obstacles—generally barbed wire—in front of first line trench, concealed, if possible, from artillery observation.
(2) Listening posts, look-out posts, machine guns.
(3) Fire trenches, recessed and traversed, or "S" and "T" types.
(4) Communication trenches to the rear, linking up the whole system.
(5) Shelters and dug-outs. These should be immediately behind the first line fire trenches, with easy communication to them.
(6) Support trenches—traversed—from 25 to 100 yards in rear of fire trenches.

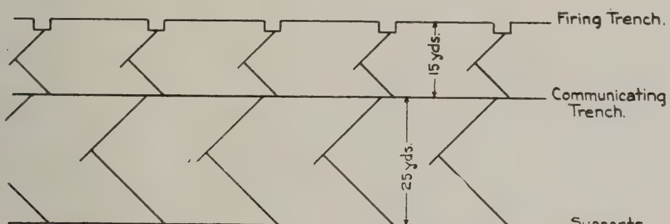


Fig. 1. Standard Field Trench.

(7) Dressing stations, kitchen, etc., branching from communication trenches.
(8) *Second line trenches.* Fire trenches, machine guns, etc., similar to organization of first line.
(9) *Supporting points, behind second line,* well defended by parties of 20 to 40 men, serve to hold up enemy assault on first and second lines; such points should be entirely surrounded by barbed wire. (P. 47, "Knowledge for War"—Capt. B. C. Lake, 1916.)

Owing to the varying stages of progress by units in their advance, fire trenches executed in the close presence of the enemy usually assume at first a disposition in irregular lines and echelons, with intervals. These receive gradual adjustment as regards alignment until *one strong line of entrenchments is obtained.* Such a line consists partly of fire trenches and partly of communication trenches linking up with the adjacent fire and support trenches. The tendency in course of time is to cover the entire frontage with a nearly continuous labyrinth of trenchwork, with the addition, in many cases, of hundreds of yards of "approach" communication trenches, from the nearest covered ground in rear of the position. Some of these approach trenches can often be prepared to act as flank-

fire trenches in case of local penetrations of the front line. Close behind these main lines of entrenchments *supporting points*, consisting perhaps of fire trenches, or closed groups of trenches, with intervals, are added at distances from *50 to 200 yards or more in rear* of vulnerable points, as an insurance against a local penetration of the foremost line. (P. 218 "Field Entrenchments"—Capt. E. J. Solano, App. VIII, Experience gained at the front, 1916)

The general scheme of the defenses consists of two wide belts of wire entanglements running the entire length of the line. Back of these, instead of a continuous line of first and second line and reserve trenches as exists on the other fronts, there is a series of small subterranean redoubts. These run the entire length of the front, and are arranged in three rows, corresponding to the three lines of trenches in the old scheme.

. . . .

The first line of redoubts is 75 to 100 feet in rear of the entanglements. The redoubts of the second line are staggered so as to cover the intervals between those of the first line. Those of the third line are similarly arranged.

Each redoubt covers an area of about 3 acres, is square in shape, and is surrounded by its own little barb-wire entanglement. It consists of an outside infantry trench, communication trenches running through it, an absolutely secure bomb-proof as a living room and refuge for the troops. the mitrailleuse positions, the observation post of the commander, and a telephone station. Each redoubt is a perfectly independent unit, compact and self-sustaining, and has a garrison of one company or less, depending on location and conditions.

. . . .

The entire redoubt is covered with natural soil or grass, and is almost invisible from aircraft.

. . . .

Regarding now the advantages of the redoubt system of defenses as compared with the continuous lines of trenches, they may be briefly summarized as follows from what appears to be obvious. First: The length of trenches to be manned in repelling an assault is less than in the continuous line system. Since only the side of the redoubt facing the enemy need be manned at the first assault, and the spaces between the redoubts are not manned, either fewer men can be employed or a more concentrated line of rifles can be obtained. The reserves must be held ready to man the other sides, if necessary, just as they must be held ready in the other system.

Second: Each redoubt is self-contained and self-sustaining, and constitutes a small stronghold independent of the rest of the line, which must be separately captured or reduced. In the continuous trench system the line is more easily pierced, and if the enemy gets a foothold in a first line trench at any point, by pouring men in at that point, he can expand in each direction, and may succeed in clearing the defenders out of their first line along an indefinite extent of front. In the redoubt system, if one redoubt is captured, the enemy's effort may be checked there and his gain localized and restricted. If the adjacent redoubts hold out they can

concentrate upon the captured one with a good chance of rendering it untenable. In this system it is therefore much easier to eject an enemy who has secured a foothold in the first line than in the old system.

Third: Each redoubt is compact and the defenders concentrated, permitting much more direct and efficient supervision and control by the commanding officer than he could exert over the long thin extended line of the old system.

Fourth: The progress of an assault can be more easily kept track of by the commanding general in rear. The points along the line are more definitely marked. In the old system it might be very difficult to know how far in each direction the enemy had been able to extend laterally in a trench in which he had secured a foothold. In the redoubt system, Headquarters is in direct communication with each redoubt, and it is known at once where the line has been pierced and extent of front lost. Adjacent redoubts report all this instantly to Headquarters, and the Commanding General, with accurate knowledge, can act with decision and co-ordinate the operations of his troops. (1916.)

The idea of a Center of Resistance in a fortified line is that, it being impossible to make the whole length of line strong enough to resist a determined attack, such as is launched in these days, the most favorable points, as determined by the terrain and by natural and artificial "points d'appui," are prepared at intervals along the front, of such resisting power that the attack must conquer each one before progressing.

The Centers of Resistance are separated by intervals not too great for mutual support, but connected across the intervals by firing and communicating trenches.

The intervals are prepared by means of dummy works to resemble the Centers of Resistance, both to the hostile troops on the ground and to the observers in the air. (A carefully made dummy trench 12 inches deep cannot be distinguished from the real thing in an aerial photograph.)

The attack will, of course, find the intervals and will penetrate and will come under the flanking fire from the Centers of Resistance. The attack may go entirely through the intervals and surround the Centers, which, however, must be reduced before definite progress is made.

The power of defense under present conditions does not consist of holding the first trench or even the second, but it lies in the ability to organize and launch the counter attack.

Officers of experience tell us that the attack and capturing the enemy's first trenches is not so difficult with proper artillery preparation, but it is the holding the gain against the counter attack coming from the trenches next further back that decides the success.

The commanders of sections do not count on holding their first trenches in case of violent attack, but always have arrangements made to counter attack. These arranegments are made beforehand down to the last detail.

However, counter attacks failing, the real resistance is to be made in the redoubts which form the keep of the Center of Resistance.

Centers of Resistance have been the stumbling blocks of most attacks. They are absolutely necessary.

With the foregoing ideas in mind, the points of the attached plans may be brought out:

Figure 2: Front for 3 companies. One company in the redoubt.

Wire completely surrounds at least two distinct portions of each company front.

Wire protects the two flanks of each approach trench.

Wire divides the redoubt into three distinct portions.

Passages through the wire in the first line are all in the re-entrants.

The redoubt is prepared for all-around defense.

The emplacements for machine guns of the first line are in re-entrants to sweep the front of the wire.

The approach trenches are provided with firing parapets throughout a large portion of their length.

Trenches for circulation extend behind nearly all of the firing trenches.

The railroad cut and fill are not prepared for defense because, for one reason, they are too well located on the general map in possession of the enemy.

Figure 3: Double line of trenches in first line.

Double line of trenches in support.

Circulating trenches behind the firing trenches of the first line, support lines, and in the redoubts.

Two distinct lines of wire entanglements in front of first line.

The whole Center of Resistance divided into two longitudinal sections, each protected in flank by wire.

Each longitudinal section divided transversely into three parts, viz.: The first line, the support line, and the redoubt, each in turn completely surrounded by wire, and each protected with firing trenches facing to the rear, as well as to the front and flanks.

Passage through the wire of the first line made continuous through the two lines, but always in the re-entrants.

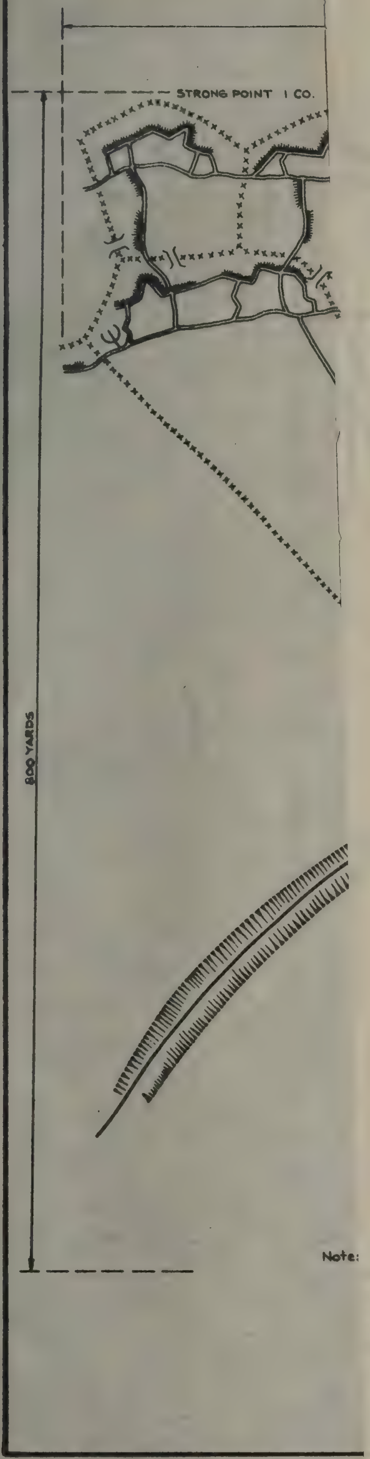
Listening posts in front of each firing trench of the first line, and placed between the two systems of wire.

Machine guns of the first line in re-entrants. Those on flanks apparently to sweep the intervals between this center of resistance and those to either flank.

Approach trenches provided with firing parapets mostly facing outward toward the wire of each section of the center of resistance. (1916.)

From the above, as well as many other reports studied, it is believed that experience thus far in Europe indicates that the proper general system of organizing a position for defense should include the following:

1st: A *front line* consisting *at first* of more or less detached and disconnected firing trenches located at the best firing points, giving about the same power of resistance to all portions of the


STRONG POINT 1 CO.
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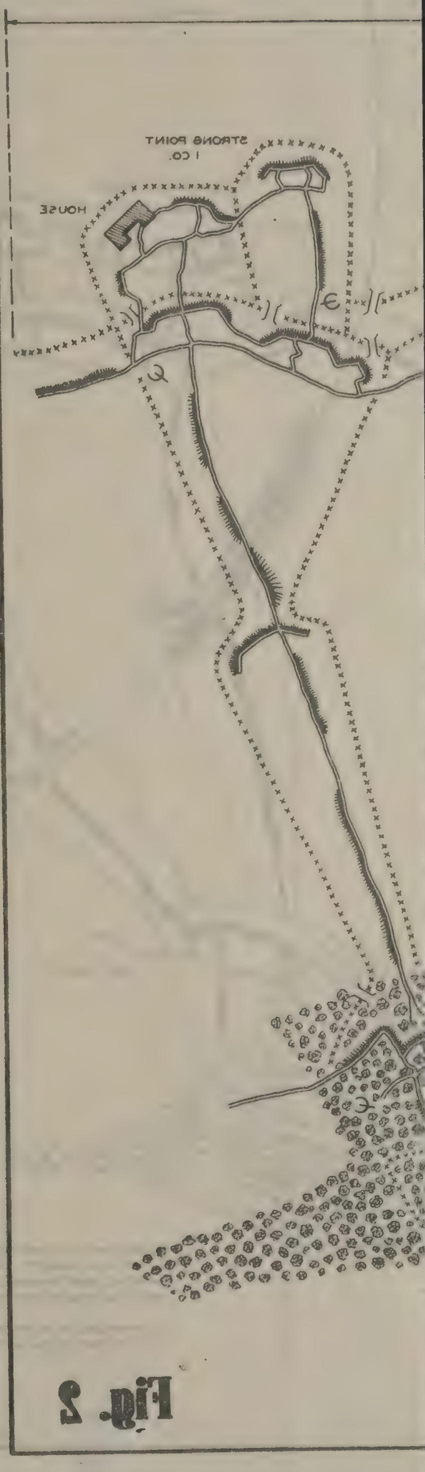
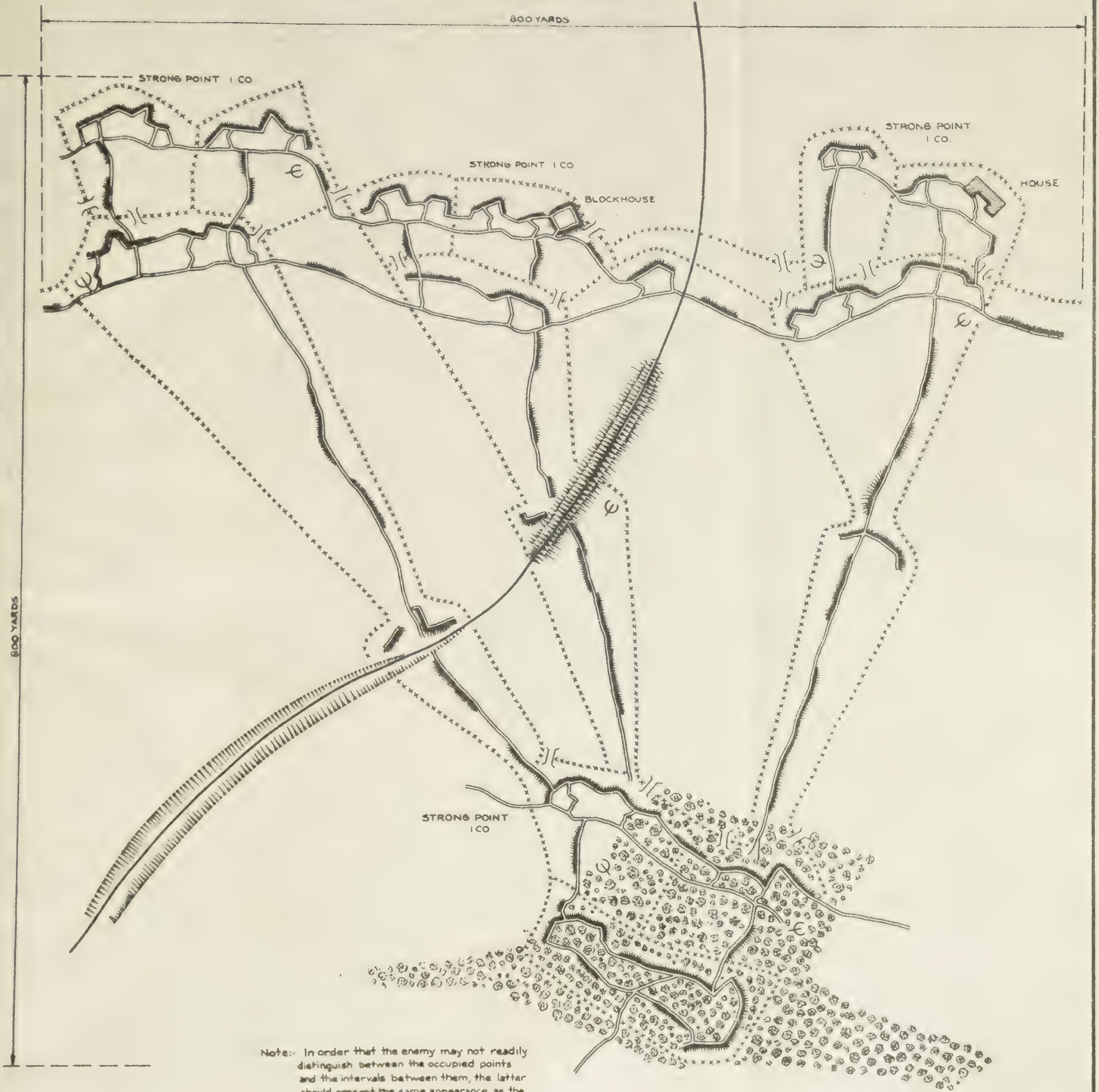


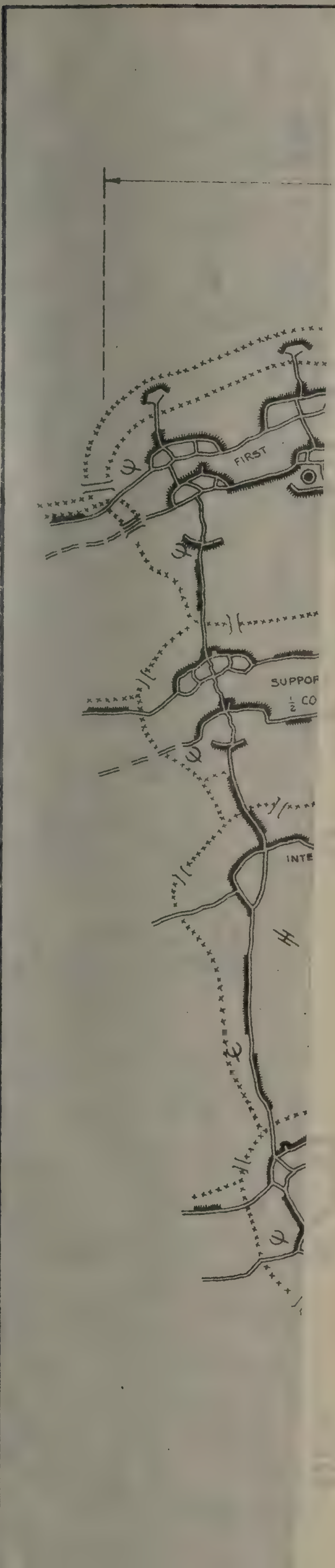
EXAMPLE OF A SUPPORTING POINT



Note:- In order that the enemy may not readily distinguish between the occupied points and the intervals between them, the latter should present the same appearance as the adjacent points.

This is accomplished by digging dummy trenches or communicating trenches in the intervals.

Fig. 2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TYPICAL SUPPORTING POINT

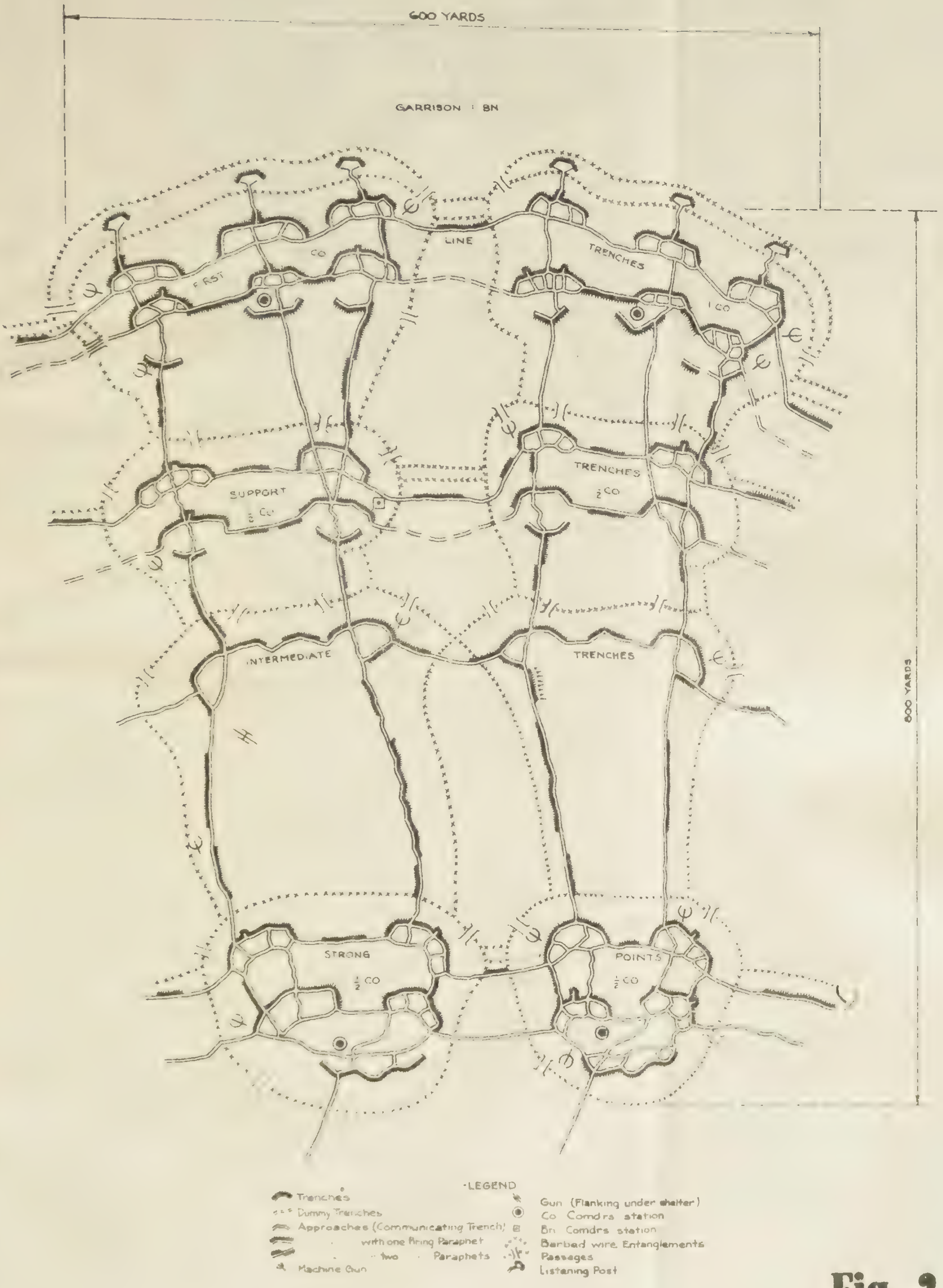


Fig. 3

front, to be afterwards connected up into almost one continuous line, consisting partly of firing and partly of communicating trenches.

2nd: In case a determined attack is anticipated, a *second* and even a *third* line, prepared in rear of the first, as rapidly as time permits. These lines may consist of a series of "*supporting points*" or "*redoubts*" prepared for all-around defense, separated by intervals more or less weakly defended (but in which numerous dummy works are placed).

3rd: Communication trenches connecting the second and third lines with the front, arranged for fire to the flanks, and protected with obstacles placed perpendicular to the front.

(*c*) The *general importance of concealment* of all dispositions and works has been emphasized in the European War, especially as regards observation from the air. But the value of concealment should apparently not be allowed to overshadow other equally important and desirable objects, which also must be considered.

The following quotations indicate the somewhat contradictory reports received, as well as some of the precautions to be taken in order to prevent observation from aircraft.

Great pains are taken to secure concealment of works. The importance of this element has increased since the introduction of aeroplane observation.

While the trenches are constructed with a view to giving as much cover as possible, and to offering the smallest target possible, no particular attempt is made to conceal them. The wire would ordinarily reveal the position anyway; but, from what I have seen, I should say that concealment is a very secondary consideration. What is sought is field of fire, and protection. (1916.)

In addition to photographs from the air of the enemy's lines, it is important to make similar photographs of the friendly lines in order that line and engineer officers may ascertain the visibility of their own works, batteries, or dispositions. (1916.)

Practically no effort is made to conceal the first line trenches, either from direct observation from the front, or from observation by aircraft. They say the enemy knows exactly where they are anyhow. On the other hand, the second line trenches and the strong points were very carefully concealed. (1917.)

A few notes obtained from air men should be of assistance to those engaged in Field Engineering Construction.

A. A long line of trenches is more visible than those arranged in groups.
B. Straight trenches are conspicuous.
C. Trenches across ploughed fields are bad and easily distinguished.
D. Straw spread at the bottom of trenches is conspicuous.
E. Trenches against hedges are invisible.
F. Very difficult to tell whether trenches are occupied or not. This also applied to gun emplacements.
G. Tracks to gun emplacements are very visible. Tracks should be made to all dummy entrenchments.
H. Cover trenches with brushwood to hide deep shadows at bottom.

When hostile aircraft are in the vicinity all officers caution their men *not to look up*, as one white face turned upwards is easily discernible from above, and might disclose an otherwise well concealed position. (1916.)

II. FIRING TRENCHES.

(*a*) *Location.* The command of the immediate foreground, even if only for a distance of from 65 to 300 yards in front of each trench, is now considered more important than a field of fire over longer ranges, especially if the location giving the more extended field of fire is more conspicuous and exposed to the enemy's artillery fire or his accurate observation. This is indicated by the following extracts from reports from various fronts:

Short fields of fire are frequently employed; sometimes due to necessity as where the trenches are located in dense woods, but often deliberately chosen to withdraw the trenches from possible artillery fire. The view is held that with a well constructed wire entanglement and a liberal use of machine guns, any sudden rush of the enemy can be checked, and it is better to sacrifice the field of fire in favor of protection from hostile artillery.

Trenches now placed by preference near the bottom of the near slope of a hill in order to protect them as far as possible from artillery fire. A clear field of 60 yards in front is enough.

The military crest was practically universally used. When this crest was wooded the trenches were usually directly in front, or the woods if not too extensive, were cut down. (1915.)

The field of fire from the trenches was relatively short—due both to the presence of woods and to the broken topography.

. . . .

The enemy's trenches were said to be very close in front, in places only 200 yards distant; they were not visible owing to the dense forest.

. . . .

It was located just inside the edge of a pine forest at a distance varying from a few feet to a hundred feet. Where the trench passed close to the edge of the timber additional screening was provided by planting evergreen branches in front.

Lying in dense woods the field of fire was necessarily very short. No attempt at clearing the foreground seems to have been made, the short field of fire through the forest trees in connection with the wire being sufficient to stop any rush of infantry. It is a question whether clearing the foreground is desirable, aside from the enormous labor involved in clearing a forest belt such a clearing would inevitably expose the location of the trench and invite destructive artillery fire.

Trenches should be sited so that they are not under artillery observation whenever possible, also with regard to POSSIBLE OBSERVATION stations on ground occupied by the enemy. This point is regarded as of great importance, and subsidiary to extensive field of fire.

A field of fire of 100 yards is regarded as satisfactory, if it can not be increased without loss of concealment from the enemy's observation stations. The concealment of obstacles to check the enemy's advance, such as barbed wire entanglements, &c., is of importance, as said obstacle enables the observer in locating and ranging on trenches in rear.

The skillful siting of trenches back of a slight rise, behind a second hedge with obstacles hidden in the same way, or entangled in the hedge in front, has been found to afford the most satisfactory concealment in the earlier stages of an attack.

Hold a wood in an advanced position or close in front with a strong overhead cover to protect the defenders from injury by falling trees.

The Importance of Screening Defence Works from the View and Fire of the Enemy's Artillery. This often tends to the selection of sites for fire trenches behind rather than in front of the crest line of a slight ridge, provided that a sufficiently clear field of fire can be obtained to deal with infantry advancing in force. 300 to 400 yards will usually be found ample; and a still shorter foreground is often considered sufficient by trained troops, provided it is clearly commanded from the firing-points, and is strengthened by a good obstacle, which would also, in such a position, be well screened from the distant view of the enemy. (P. 215 "Field Entrenchments"—Capt. Solano, 1916)

(*b*) *Trace.* The following types of trace have been used in Europe:

1. *"Sinusoidal" or wavy;*
2. *Indented;*
3. *Traversed;*
4. *Traversed and recessed;*
5. *"S" and "T";*
6. *Bastion.*

These are illustrated and referred to in the following quotations. The *ordinary traversed trench seems to be in most general use,* although the "S" and "T" type is apparently used quite extensively, and some new lines recently constructed show evidences of returning to the "bastion" trace.

The tendency is to resort more and more to "sinusoidal" trenches, which have been found more economical to build; care is taken to make these trenches wide enough and the curves gentle enough for stretchers to pass through. (1916.)

The perpendicular distance between the axes of the longer straight elements (see Fig. 4) should not be less than 5 feet; and these elements should not be longer than 6 yards.

. . . .

In places particularly exposed to enfilade fire, individual niches for riflemen should be constructed between the traverses. (Fig. 5.)

These afford efficient protection against enfilade fire. They are often constructed in old trenches which have been damaged by projectiles or bad weather. (1917.)

"*S and T*" *trenches* consist of a number of short lengths of fire trenches connected to a lateral communication trench of "S" design immediately in rear (see Fig. 6). (P. 52 "Knowledge for War"—Capt. Solano, 1916)

The main excavation along the front is continuous 7 or 8 feet deep, and 4 or 5 feet wide, and not loopholed or otherwise prepared for defense.

The actual firing trenches are dug five or ten feet to the front and reached by a short communicating passage. They are not continuous, but each is arranged for a squad or so. In rear of the main trench, and reached also by short passages, are the excavated quarters for the officers and men.

They have returned to the *continuous* line of trench, and I believe that in many of the new trenches being put in, the form of the trace is such that the trench traverses itself automatically, while the entire crest is available as a firing crest providing its own flank fire (see Fig. 7). (1916.)

The first line trench is divided into sectors, each held by a unit of about 30 men, and separated from adjacent sectors by loopholed traverses completely closing each end. A narrow communicating trench leads into the sector from the rear, and communication with the adjacent sector is afforded by an underground passage leading around the inner end of the traverse. Fifty feet back of the first line trench and parallel to it runs a second firing trench with banquette four steps high, and the ground in front so sloped as to give it full command of the first trench. The effect of this arrangement is to make it extremely difficult for the enemy to advance from, or even to hold, the first line trench should he succeed

Fig. 4. Indented trace.

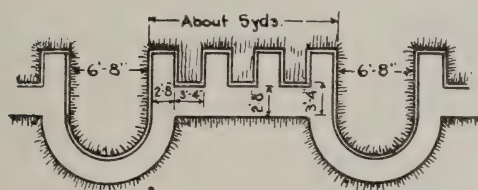


Fig. 5. Individual niches (or traversed and recessed type).

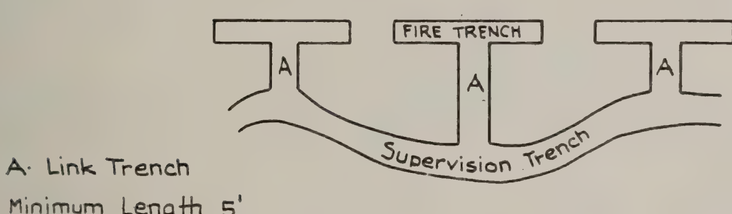


Fig. 6. "S" and "T" trench.

Fig. 7. "Bastion" trace.

in gaining a foothold in one or more of its sectors as a result of surprise, mine explosion, sudden intense bombardment or other device. Not only would the assailants be swept by fire from the supporting trench in the rear, and from the adjacent sectors, but their only means of access to these positions, except by climbing out over exposed ground, are passages so narrow that men can advance in them only one at a time.

(*c*) *Traverses.* The practice in regard to dimensions and spacing of traverses varies considerably, but the tendency is to make them *thicker, longer,* and *closer together,* than was the practice prior to the war. It is believed the following might be adopted as a result of experience to date:

(1) A minimum thickness of 6½ to 7 feet;
(2) A length sufficient to overlap rear of trench at least 2 feet;
(3) Space between traverses varying from 4 to 8 yards, depending on danger of enfilade.

The following quotations indicate the variety of practices in this respect in Europe:

Where traverses are employed they are given a width of 5 feet, while the length of parapet between the traverses is generally 5 yards. (1916)

The traverses were eight or nine feet broad.

The trenches, as a rule, still show the form with the traverse attached to the front, and spaced from 8 to 30 yards, depending on the trace of the trench. (1916)

Traverses are provided every ten paces, and are two to three feet thick.

The traverses were unusually large, being approximately 20 feet square. The firing trenches between the traverses were about 30 feet long. (1917)

Traversing should be carried out at frequent intervals—say, every four or five yards on the average; and firing recesses made where a trench is likely to be exposed to enfilade fire. (P. 216 "Field Entrenchments." —Capt. Solano, 1916)

The bays of a fire trench should be 12 feet to 15 feet long. Longer lengths than 18 feet invite heavy casualties in cases of enfilading and of the burst of high explosives in the trench.

. . . .

The traverse of the parapet must overlap the parados traverse by at least two feet. (P. 49 "Knowledge for War"—Capt. Lake, 1916)

The best method for defense against enfilade fire is to localize the effect of projectiles by employing traverses. (Fig. 8)

To give protection against the effect of heavy artillery, the traverse must be at least two yards thick on top. In places exposed to direct fire, this thickness must be increased to three or four yards, depending upon the character of the soil. In depth, the traverse should project at least one yard beyond the face of the rear wall of the trench. The interval between traverses should be from six to eight yards. In exposed places this interval should be reduced to four or five yards. (1917)

(*d*) *Profile.* The tendency appears to be about as follows:

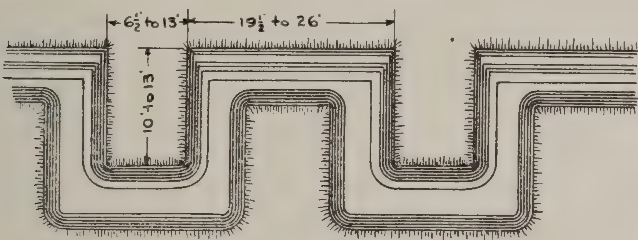


Fig. 8. Traversed trace.

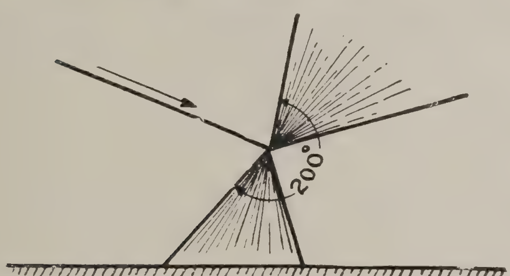


Fig. 9. Angle of dispersion of fragments from high explosive shell.

1. To make the trench as *narrow* and *deep* as possible, and suppress the parapet, usually making it about 1 foot, and not more that 1.5 feet high. Total relief of complete trench usually about 7½ feet. Width at ground level not more than 5 feet.

2. The elbow rest is *retained* in all recent profiles, although early reports were to the contrary.

3. A *parados* is added in rear, to give shelter from the "back blast" of high explosive shell. The necessity for this is shown in Fig. 9, below.

4. Vertical height from firing step to top of parapet should apparently be more than 4½ feet as formerly used—probably about 4 feet 9 inches.

The latest profiles adopted by one of the belligerents developed from the skirmisher's shelter to the completed trench, as given in a recent lecture on field fortifications at a training school for officers, are shown in figure below:

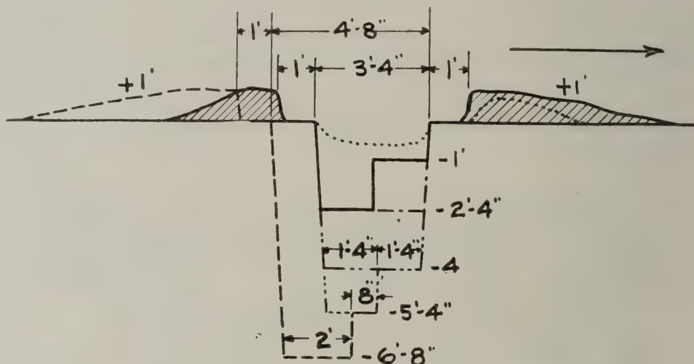


Fig. 10. Normal profiles of firing trenches.

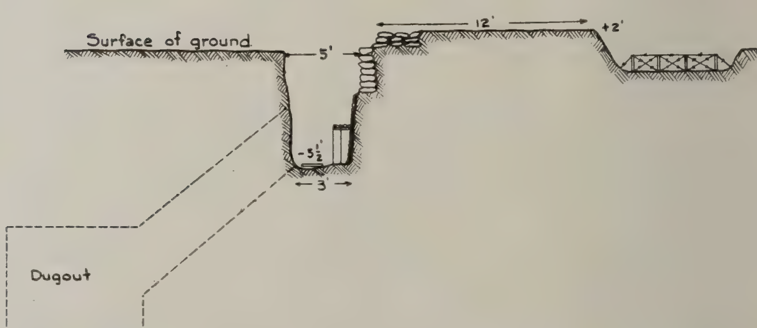


Fig. 11. Profile of a firing trench.

Skirmisher's shelter,	thus	
Firing sitting,	" ————————,	constructed in from 30 minutes to 1 hour.
Firing kneeling,	" — . — . — . —,	constructed in from 40 minutes to 1½ hrs.
Firing standing,	" — . . — . . —,	constructed in from 1¼ hours to 3 hours.
Firing standing, and shelter standing,	" — . . . — . . . —,	constructed in from 1½ hours to 3½ hrs.
Completed trench,	" — — — — —,	constructed in from 3 hours to 7 hours.

(Note: Task 7 feet long for 2 men, with 1 pick and 1 shovel, spelling each other.)

A type in use by another belligerent, and constructed recently at one of the training camps, is shown in Fig. 11.

Sketch of a very recent type in use on the Eastern Front by

still another belligerent is shown below, together with a description of same:

In profile, the fire trench is of the sunken type, the elbow rest, or berm coinciding generally with the natural ground. The total depth, or cover, of the trench is held at about 6½ feet, being less than the depths noted on the west front at the end of the year 1915, which approximated 10 feet in places. While excessively deep trenches with steep side slopes give increased security against shrapnel and shell splinters, they are more easily broken down by heavy shell fire and more difficult to restore. Reports from a recent battlefield indicate that too great a depth of trench is a disadvantage and apparently a reaction has set in, in favor of a more moderate depth, namely about 6½ feet. In the lower portions of the trench, concrete is extensively employed as a revetment and as a floor covering, being applied in situ with a reinforcing wire mesh. For the upper part of the trench sod is commonly employed. A typical trench profile is shown in the accompanying sketch (Fig. 12). (1916)

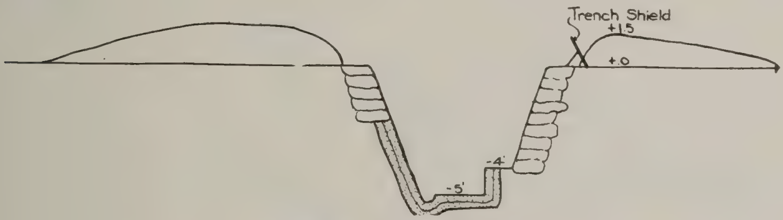


Fig. 12. Normal profile of a fire trench.

The great depth and narrowness of the trenches generally is a noticeable feature. (1915)

The trenches were about ten feet deep with two steps leading up to the firing position; there being room for three men to fire in each bay.

In this war 80 per cent of the casualties are said to be caused by artillery fire, and the shell is more feared than the shrapnel. Therefore, the trenches must protect against the back-fire of shell, and the trenches must be so arranged as to confine the effect of the projectiles to the smallest practicable space and number of men.

There was the same berm or shoulder rest that we use. (1917)

The height of the parapet should be almost nil.

. . . .

Earth not required for the parapet should be placed behind and close to the trenches to afford protection against the back blast of high explosive shells, provided the trenches are not rendered conspicuous thereby.

. . . .

All elbow rests should be dispensed with or made as narrow as pos-

sible. Most men, however, prefer making their own niches for the fore-arm to rest against.

Trenches should be deep, and as narrow as will permit of free movement. Firing steps, if firmly revetted, may often be reduced in width to 12 or even 9 inches, if the toes can be dug forward into the interior slope.

. . . .

As far as possible visible parapets should be dispensed with.

. . . .

The value of elbow rests is not generally found to outweigh the importance of good cover close to the shoulder. (PP. 216-217 "Field Entrenchments"—Capt. Solano, 1916)

Fire trenches must be prepared at the best firing points. They should

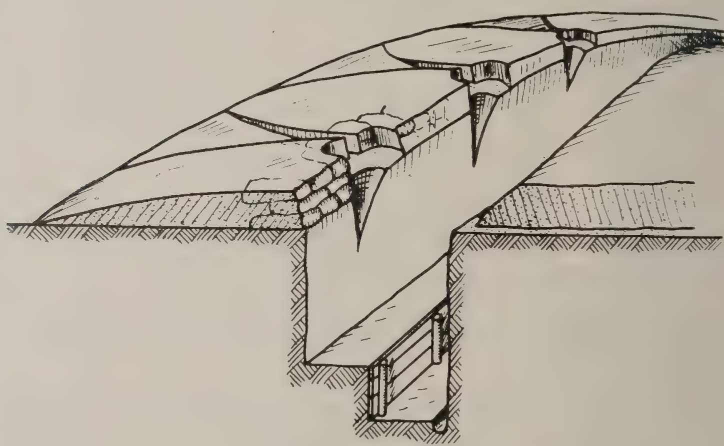


Fig. 13. Fire trench with individual elbow rests and niches.

be as narrow as possible at first. Subsequently they may be widened and deepened, leaving a firing step, which must be revetted.

The height over which an average man can fire is 4 feet 6 inches, but a man can fire comfortably enough over five-sixths of his own height. To make firing positions as convenient as possible, the simple expedient shown in Figure 13 may well be adopted if trenches are occupied for any length of time. (P. 49 "Knowledge for War"—Capt. Lake, 1916)

Each rifleman arranges the bottom of the trench or the firing banquette (lowering it or raising it) to suit his height.

Each rifleman makes a groove-loophole in the crest of his parapet.

Each rifleman fixes up a notched arrangement for firing at night (verified by the chief of the Section).

Each rifleman makes holes in the wall (the enemy's side): 1. for cartridges; 2. for the pouch. (1917)

(*e*) *Head cover and loopholes.* The reports from Europe give details of many different kinds of head cover and loopholes, which apparently were quite generally used on the Western Front by both sides, but the indications are that as experience was gained with them, their disadvantages for general use became more apparent, and now they are being used more sparingly. It is believed that experience indicates that they should only be considered for use in special cases where their many disadvantages are no drawback, and then all possible means should be taken to conceal them from discovery by the enemy. The use of steel loophole plates is quite general by all the armies, and it is believed a plate of this kind should be adopted for our troops, and a certain number kept on hand for issue.

The experience with head cover may be gathered from the following:

In some places the parapet was notched for the rifleman.

. . . .

No overhead cover was provided along the parapet, but there was plenty of head cover, such as head logs, steel shields $\frac{3}{8}$-inch thick, sand-bags, and hopper loopholes.

. . . .

Four or five loopholes were built between each pair of traverses, some being steel shields, some sand-bags, and some of hopper type.

Each short straight stretch between traverses was divided into two parts, one open, and the other provided with two or three feet of overhead cover; this cover is at just the height to give head room to the men peering through the loopholes at the level ground in front.

As I now understand it, the loophole is suppressed, only one or two per section (50 men) here and there for the lookouts, being left. The men fire over the parapet without head protection once the attack shows itself within range. (1916)

I saw practically no head cover for riflemen, but there were occasional loopholes for snipers. (1917)

Headcover and overhead cover, as shown in Manual of Field Engineering, is impossible, except at certain points which are to be used as observation stations, and which must be most carefully concealed.

Headcover and overhead cover restrict the free use of the rifle and bayonet when the trenches have been rushed by the enemy.

Where headcover can be constructed to advantage, a continuous loophole is considered the best form.

Troops have from experience discovered a good many disadvantages of loopholes as follows:

They are mostly of use only to snipers, and are of no use in repel-

ling an attack. They afford a very limited field of fire, and when the enemy is charging he can to a certain extent avoid them; then before the soldier can get his rifle out of the loophole to use his bayonet, the enemy is upon him. It is much better to shoot right over the parapet and be done with it. If you do have wooden loopholes (or any other kind it would seem) it is better to point them obliquely so that the enemy cannot readily see or shoot through them. They may also be covered by a curtain at the inner end to cut off the light, or a shield to stop bullets. The view through them from the defender's side may easily become obstructed by a bit of grass, sod, or earth turned up by a hostle bullet, and it is sometimes necessary to crawl out at night and clear up the field of fire.

Headcover and overhead cover in the cover trenches is valuable, but overhead cover in the firing line must be used sparingly if it will interfere with the rapid use of the bayonet when no obstacle intervenes between opposing trenches at close quarters. (P. 216 "Field Entrenchments"—Capt. Solano, 1916)

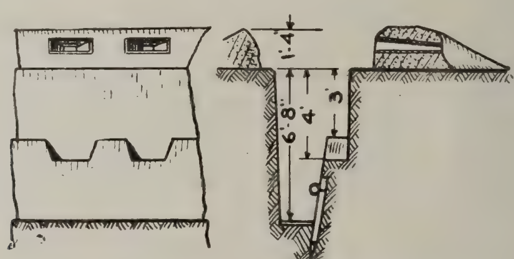


Fig. 14. Arrangement for fire over parapet.

Disadvantages of loopholes:

Difficulty of concealing firing points. Loopholes give snipers an easy mark.

They lessen number of rifles that can be used at a given point.

The necessary headcover makes it more difficult to get out of the trench quickly.

Damaged headcover often spoils a good firing point. (P. 59 "Knowledge for War"—Capt. Lake, 1916)

General remarks on head cover—

It should be concealed by using grass, brush, canvas, empty sand bags, etc.

The sky as a background should be avoided by raising the parados, or placing a canvas curtain behind the rifleman's head, and closing the opening with a cover which can be removed when the loophole is in use.

In addition to its visibility, head cover has the disadvantage that it causes a pause in the fire of the defender when the attack reaches the most deadly zone of fire, because the offenders have to withdraw their rifles to prepare for bayonet fighting. It is therefore necessary to ar-

range for fire over the parapet. For this purpose banquettes can be constructed of sod, stone, logs, or scaffolding, between the loopholes (Fig. 14).

In some sectors the loopholes have their axes inclined to the normal.

Every loophole intended for observation should be placed obliquely in the parapet in order to be protected against shots from the front. (Fig. 15).

In some sectors loopholes should not be used at all. (1917)

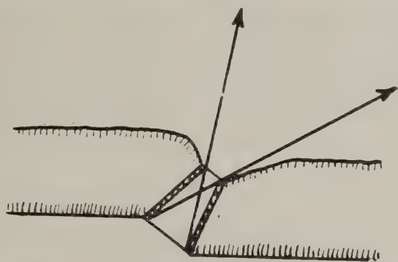


Fig. 15. Loophole placed obliquely.

(*f*) *Means for getting out of the trenches* in order to make an attack, or to resist an attack with the bayonet are usually provided as shown below:

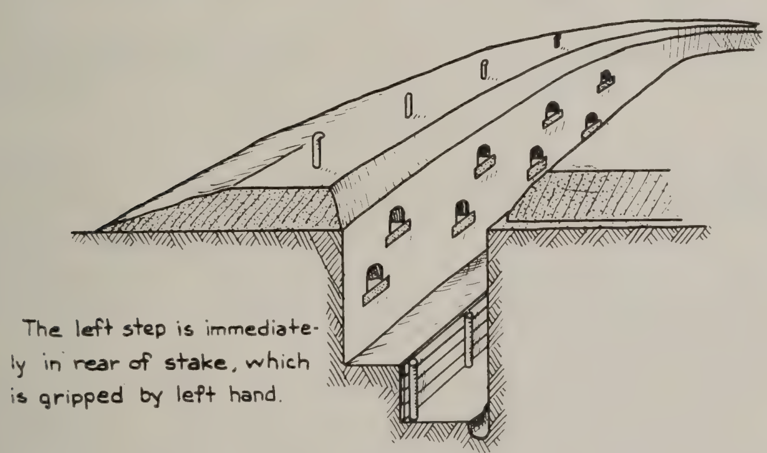


Fig. 16. Fire trench, showing sortie steps and stakes.

Men must be able to get quickly out of the trenches to repel possible attacks with the bayonet. Steps, strengthened with brick or stout wood, may be used, but care must be taken not to weaken the parapet overmuch. (P. 49 "Knowledge for War"—Capt. Lake, 1916)

Type of sortie steps as described in a recent lecture on field

fortifications at a training school for officers, is shown in Fig. 17.

III. COMMUNICATIONS.

While the importance of providing ample communications between all elements of a command, whether in the attack or the defense, has always been recognized, it is believed that the experience in the European War has first brought out the difficulties attending the control of troops when moving through a maze of narrow trenches, and for that reason this war has perfected many details in regard to this branch of field fortification, which were previously in a more or less indefinite or unfinished state.

The importance of the subject may be gathered from a recent paper on the "Organization of the Attack," by a battalion com-

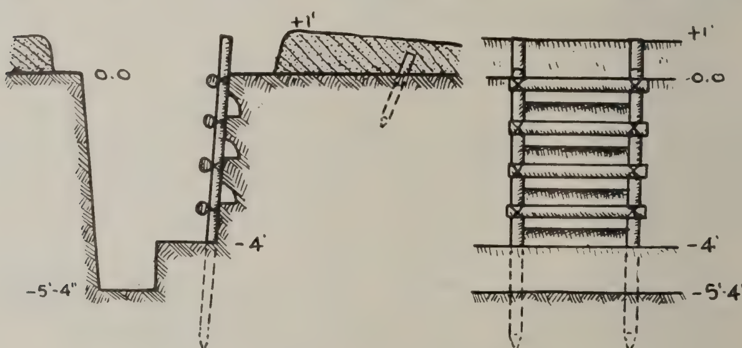


Fig. 17. Sortie steps.

mander of one of the belligerent armies, who has had considerable experience:

> Less emphasis is laid on fire trenches than on communication trenches, because, in case of necessity, resistance can be made in any kind of a trench, while it is impossible to move at all freely in communication trenches, which are badly made or in bad repair.

Some of these recent developments are as follows:

(*a*) The almost universal adoption of a *lateral communication trench,* variously referred to as "supervision," "back," or "circulating" trench, 10 to 15 yards in rear of, and generally parallel to, the firing trench.

> Ten or fifteen yards behind and parallel to the firing trench and connected with it at frequent intervals runs a narrow communicating trench.

> About 25 yards in rear of the firing trench and paralleling it is what

is called a supervision trench. It has the same profile as the communication trenches, and is slightly zig-zagged or ∿ -shaped. It is used for lateral communication along the firing trench as one can pass along it much quicker than along the crowded firing trench. It also is used as a place to take up the overflow when reliefs are changing in the firing trench, the new relief being placed in the supervision trench while the old relief files out of the firing trench, thus avoiding congestion in the communication trenches. (1917)

(*b*) The use of "*zigzag*" or "*wavy*" trace for trenches for evacuating the wounded, as they are easier to carry litters through than the *straight traversed* trench, which, being shorter, and more easily defended in case of capture, is much used for bringing up supplies and reinforcements:

The communicating trenches between fire and cover trenches, usually 80-100 meters apart, are now generally blinded throughout their entire length. (1916)

Communicating trenches were always S or snake shaped, the amount of curvature being left largely to individual judgment. These communicating trenches were narrow, barely allowing two men to pass; they were dug to about 6 feet depth, and with the excavated earth gave a protection of about 7 feet. No zigzag communicating trenches were seen at all. (1915)

A trace with gentle curves, does not protect from enfilade fire and cannot be defended by flank fire. The only traces that should be used are: the stepped; the traversed; and the zig-zag.

. . . .

The stepped and traversed traces are preferable for communicating trenches that are used for bringing up men and supplies as they are shorter; the zig-zag trace is better for the evacuation of wounded, as the litters can be carried around the turns easier. (1917)

(*c*) *The arrangements made for defending the communication trenches,* and preventing the enemy from advancing through them, after he has once obtained lodgment therein. This includes machine gun emplacements, or loopholed traverses, arranged to rake the straight portions; portable obstacles to be quickly placed to block the passageway; and numerous forms of traps which are more ingenious than they are important:

Every now and then in this trench a wall was fitted up with loopholes for two or three rifles or a machine gun, so placed as to permit firing down the trench. Generally in front of these places a tangle of barbed wire was hung overhead so that in case of retreat it could be dropped down to fill the trench.

The communication trenches are in places covered by a traverse as follows:

There are two loopholes running through the traverse, made of inch boards about 6″×6″. (1916)

At intervals along the communicating trench are accommodated a supply of portable obstacles which can be quickly pulled into the trench, thus obstructing an advance of the enemy by this route. At intervals sortie steps are constructed to permit troops of the defense to debouch in launching a counter attack against the first line trenches. A further defensive feature is the occasional introduction of an elevated platform across the communicating trench at the angles from which one or two men with hand grenades can conveniently oppose an advance along the trench. (1916)

Straight communication trenches are now being made with a loop-

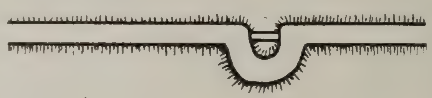


Fig. 18. Traversed communicating trench.

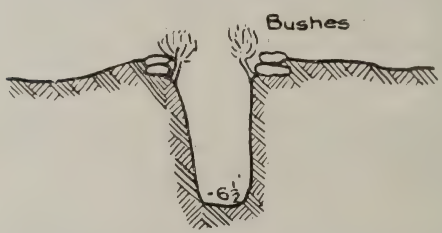


Fig. 19. Profile of communication and supervision trenches.

holed traverse or machine-gun emplacement at the rear ends, to repel an enemy who may gain the fire trench. In constructing a straight communication trench, the following points must be borne in mind:

(a) Long straight lengths are most conspicuous and easily seen from aircraft.

(b) Danger from enfilading is great, and a "shell burst" would effect a maximum number of casualties. (P. 52 "Knowledge for War"—Capt. Lake, 1916)

Communication trenches: About 2 feet wide at the bottom and 3 feet at the top, 7½ feet deep (Fig. 19). They usually lead straight back from just behind a traverse, the straight portion being extended about 75 yards back and protected by several flying traverses, which are simply logs laid across the top of the trench for about 6 feet, and covered with two layers of sand bags to prevent bullets and shrapnel from falling into the trench (Fig. 20). Then the communication trench is zig-zagged back to the

second line. At the rear end of the straight portion of these trenches is a covered machine-gun emplacement to rake the 75 yards of straight communication trench in case the enemy takes the firing trench. (1917)

(*d*) The *frequent provision of communicating trenches arranged for fire to one or both flanks* with obstacles paralleling the trenches to provide defense against flank attacks:

The communicating trenches connecting the first and second lines of

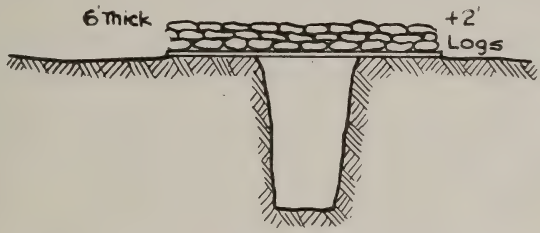


Fig. 20. Flying traverse on communication trench.

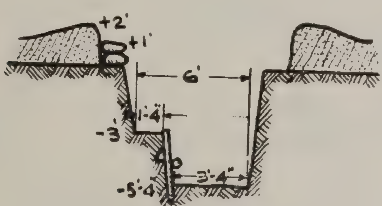


Fig. 21. Communicating trench with single fire crest.

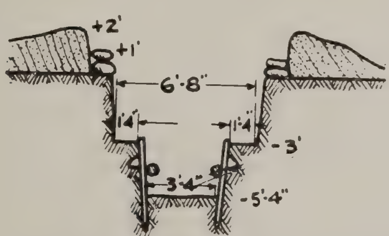


Fig. 22. Communicating trench with double fire crest.

trenches, usually some 90 yds. apart, have the usual zig-zag trace to limit the effect of enfilade fire. In addition they are now provided with certain accessory features to enable them to be employed as defensive trenches and to serve as starting points for counter attacks in case the first line trenches have been temporarily lost. These communicating trenches are, first of all, arranged with firing banquette at intervals from which a flank fire can be brought to bear upon the enemy if he endeavors to pass over the open ground in rear of the first line of fire trenches. (1916)

Communications to the front and rear. These connect up the successive lines of trenches. They should be protected on both sides by barbed wire entanglements. Some are arranged for firing, and are provided with a firing banquette and elbow support (see Figs. 21 and 22). (1917)

(*e*) The provision of a *berm* along both sides, about 1 foot wide, to prevent earth from continually falling back into, and blocking up, the passageway:

There should be a berm of about a foot on both sides (see Fig. 23) :—

1. To prevent the earth from falling into the trench and making it muddy.
2. To form a small platform for tools, packs, and rifles; and to give more space for two columns to pass each other.
3. To permit infantrymen with packs to leap over the trench. (1917)

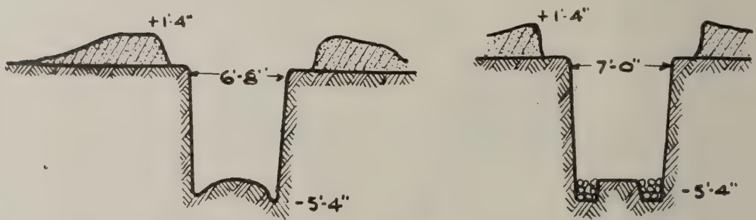


Fig. 23. Communicating trenches.

(*f*) The importance of *keeping these trenches clear*, providing for *drainage*, *revetment*, *widening* at the turns, *lighting* at night, and *marking* with signboards especially if the trenches are to be in use for any appreciable length of time:

A part of a parallel should never be used as part of an approach, as DABC (Fig. 24). Besides causing confusion it renders passage through the approach difficult when the parallel is occupied by troops.

. . . .

The bottom of the trench should be constructed and maintained slightly convex for drainage, or a ditch, filled with small stones, should be constructed on both sides (see Fig. 23).

. . . .

At all branches there should be placed in each branch, two solid sign-posts, planted firmly in the berm beyond reach of accidental blows, and also a niche where a lantern can be placed;

. . . .

Besides sign-posts, the principal approaches are distinguished from the minor ones by making them from 1 foot to 1 foot 4 inches deeper at all forks or crossings. (1917)

(*g*) The multiplicity of *telephone lines,* and need for installing important lines in duplicate, and within easy reach for repairs.

Telephones are always used double, that is, two entirely independent lines to every place. (1917)

It was learned that the attempt to bury wires to avoid damage caused much trouble, as the breaks caused by fragments of shells penetrating the ground were very difficult to locate.

While the telephone is the most satisfactory means of communication under ordinary circumstances, it has been found that the intense bombardments that now usually precede attacks are apt to cut most or all of

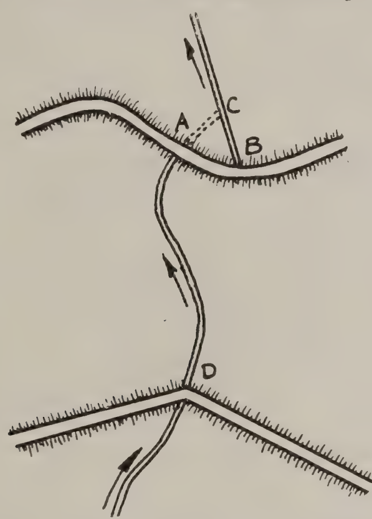


Fig. 24. Continuity of the trace.

the telephone lines, so that alternative means of communication are absolutely essential. (1916)

During a bombardment, communication becomes very difficult, but it must be maintained by all possible methods. This may be accomplished by:

1. Installing telephones under strong shelters.
2. Using lead covered cable, buried 6 feet deep, especially for the lines connecting the regimental, brigade, division, and corps headquarters.
3. Placing rockets in all shelters and observatories where officers or non-commissioned officers are posted.
4. Preparing posts for visual signalling, safe from bombardment and defiladed from view of the enemy. These posts are constructed in shelters similar to those for searchlights, and are provided with horizontal loopholes, with the opening to the flank or rear. (1917)

IV. OVERHEAD COVER.

The necessity of obtaining, as soon as possible, *effective protection against artillery fire* is believed to be one of the most important lessons of the European War. Due to the increased caliber and range of modern mobile artillery, and the large use of high-explosive shell, coupled with enormous ammunition supply, it is almost impossible to hold any position gained unless immediate protection from this fire is secured.

This desired protection is partially obtained by efforts to conceal and to screen wherever possible, and to avoid crowding the personnel into small spaces, thus furnishing good targets for the enemy's artillery; but, due to the improved methods of observation afforded by modern aircraft, this form of protection must be sup-

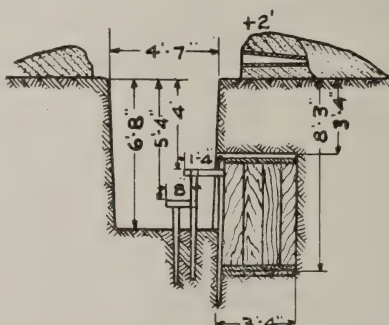


Fig. 25. Shelter under parapet.

plemented as rapidly as time and materials permit, by furnishing *actual material overhead cover for the entire force.*

(*a*) "*Splinter-proof*" overhead cover, furnishing protection only against shrapnel bullets, seems to be *used very little*, and the first overhead cover sought is apparently that furnishing protection against the high-explosive shell of the 3-inch gun. A simple form of shelter, which gives this protection rapidly, and is the result of at least two years' experience of warfare, is illustrated and described below:

Shelter under the parapet. These shelters for rest and protection against artillery fire, can be rapidly and easily constructed (Fig. 25).

They must—

1. Not interrupt the line of fire.
2. Be capable of execution after the trench is finished.
3. Permit a rapid sortie.

They should be about 3 feet 4 inches wide, 5 feet high, and 6 feet 8 inches long; and will shelter from 6 to 8 men. The overhead cover should be at least 3 feet 4 inches plus the height of the parapet. In earth they should be lined. Wooden steps should replace the firing banquette, which must be removed in excavating the shelter. (1917)

(*b*) With reference to the *thickness of overhead cover required*, the following extracts show the result of experience in Europe:

The roofs of dug-outs are thickened in order to resist the burst of a high-explosive shell as follows:

Against the 3-inch shell a bed of timbers from 8 inches to 10 inches in diameter, and 12 inches of earth.

Against the 4.2-inch and the 6-inch shells, *two* beds of timbers and *two* beds of earth.

Against the 8.4-inch shell, *three* beds of timbers 12 inches in diameter, and *three* beds of earth 12 inches thick.

The beds of timbers may advantageously be replaced by a bed of railway iron and a bed of sacks of hardened cement.

The timbers and the rails should be securely fastened together. One of the beds of earth may well be replaced by a layer of stones, which gives a hard bursting surface. (1917)

Effective resistance of roofing materials.

Shrapnel bullets. Stout planks suitably supported, covered with corrugated iron and 12 inches of earth or 3 inches of shingle.

Ordinary field guns of 3-inch calibre. Strong timber supporting 4 feet of earth, with a top layer of heavy stone or broken bricks to cause early shell burst.

Field howitzers (of less than 6-inch calibre), 12-inch logs, supporting 8 feet of earth.

"Jack Johnsons" 20 feet of earth or 10 feet cement concrete, reinforced with steel. (P. 56 "Knowledge for War"—Capt. Lake, 1916)

(*c*) The necessity of having good *shelters close to the firing trenches*, either leading directly out of those trenches, or out of parallel communicating trenches, 10 to 15 yards in rear; the very *thick overhead cover provided*, never less than 8 or 10 feet, and more recently usually 20 to 25 feet thick; the necessity of providing a *number of small shelters*, rather than a few large ones; and the almost universal use of *two entrances* to shelters, in order to avoid the liability of egress being prevented by the entrance being blocked; are all believed to be practices which have been well established by the experience to date in the European War, and which may be accepted as essential for any stubbornly defend-

ed position. The general use of these methods may be appreciated by referring to the following:

Cover trenches are required to be close up—say 15 to 25 yards in rear of the fire trenches—with shelters in which men can sleep. (P. 216 "Field Entrenchments"—Capt. Solano, 1916)

Shelters were very deep, some with spiral staircases. All appear to be connected by underground passages to each other and back to second line.

There was no head cover for protection against shrapnel fire as we make it, but instead there were many bomb-proofs, little chambers about 6 feet square and five feet high, which were dug way down under the parados with about 8 feet of earth above. These bomb-proofs were entered by a passageway about 2 feet wide, 4½ feet high, and 15 feet long, sloping downward. There were enough of them, together with the machine gun emplacements, to shelter the entire first line garrison. (1917)

From time to time steps wind down from this supervision trench to subterranean chambers, with 5 meters of natural earth cover, used as shelters when trenches are bombarded by heavy artillery. Inside they are 30 feet long by 8 feet wide, and 7 feet high, with a board platform 6 feet wide on the ground, and another 3 or 4 feet above it, both running the full length of the chamber for the men to sleep on. From each end steps lead up to the communicating trench.

All the trenches are liberally provided with underground shelters having an overhead cover of some 10 or 12 feet of undisturbed earth;

. . . .

Every shelter has two entrances.

. . . .

As a result of these arrangements, although bombarded daily in some sort for 6 months, but one man had been killed in the trenches.

The so-called "fox" holes or mined galleries under parapets, introduced early in the course of the position warfare are being made still deeper, and now have 20-26 feet of solid earth as cover, and never less than two entrances which are given a curved or broken direction to keep out shell splinters. (1916)

Ample living accommodations for the trench garrison is provided behind the fire trench with short communications. These accommodations present the usual features of splinter-proof covers for living rooms, kitchens, latrines, dressing stations, etc. to meet a long continued heavy bombardment by heavy artillery, such as now precedes every determined attack against a strongly fortified field position, special arrangements have been provided. For the security of the personnel, deep bombproofs have been constructed along the fire trench, generally three to each full company, each bombproof capable of accommodating 60 men. These bombproofs have 16 to 17 feet of earth cover, a steeply inclined stairway, start-

ing from the interior slope of the trench at each end and are roomy enough to admit of a double tier of sleeping bunks. In the side walls of the stairway and bombproof there are niches for ammunition, hand-grenades, food and water, intrenching tools, etc. These bombproofs are provisioned for 8 days, so that its occupants can hold out this long, if necessary. A special type of sanitary trench latrine or closet also forms part of the furniture of each bombproof. (1916)

During a heavy bombardment which renders the trenches untenable,

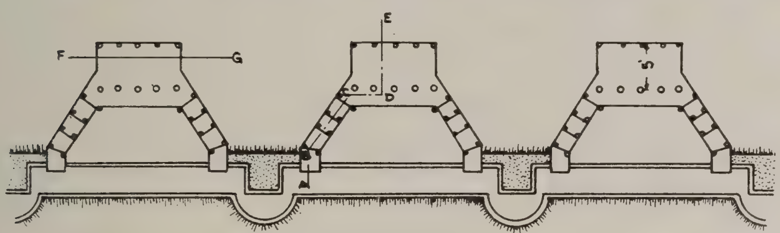


Fig. 26. Plan of cave shelters.

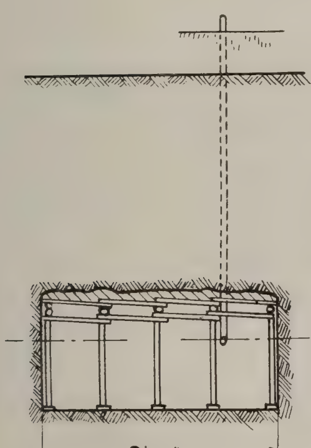


Fig. 27. Section F-G.

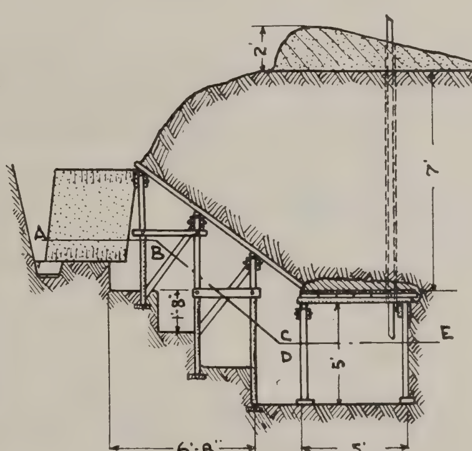


Fig. 28. Section A-B-C-D-E.

the personnel must be sheltered so that it will be available at the moment of assault. For this purpose shelters should be constructed with logs, earth, steel rails, or concrete, and by sinking them from 25 to 40 feet under solid ground. (See Figs. 26, 27 and 28.)

To limit the effects of hits, only small shelters should be used. Their maximum capacity should be from one to three squads.

. . . .

These shelters should be constructed on branches from the fire trench or from a communicating trench, at a distance of 10 to 12 yards from the fire trench.

Two entrances should be provided as they are liable to be obstructed

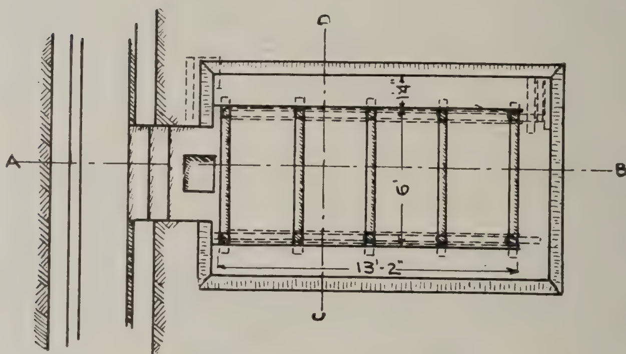


Fig. 29. Plan of a shelter.

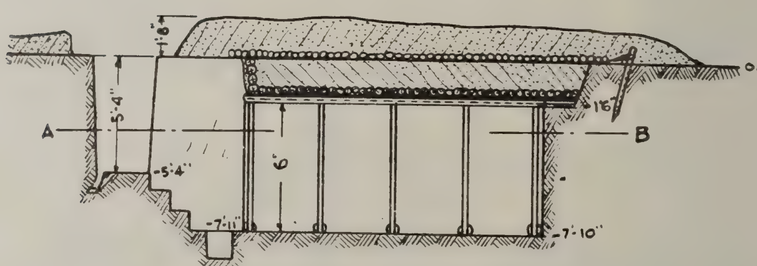


Fig. 30. Section A-B.

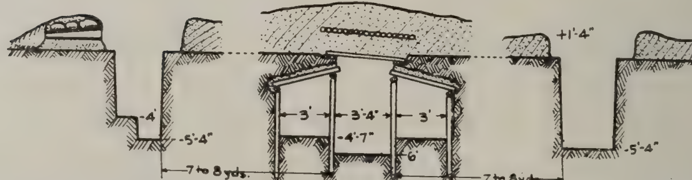


Fig. 31. Details of shelters constructed on a special communicating trench.

by caving in. The entrances should not be placed on opposite sides of a traverse as a hit on it might obstruct both entrances. Observation from them may be provided by boring a hole with an earth auger to the surface of the ground, in which a periscope can be used. Ventilation is obtained in the same way. As the shelters are lible to cave in, especially at the entrance, picks and shovels should be stored in them, and arrangements made for their ventilation. (1917)

(*d*) Some other types of shelters used on the Western Front, and illustrated and described in a recent lecture at a training school for officers of one of the belligerent armies, are shown below:

The shelter shown in Figs. 32 and 33 is intended for a garrison of 25 men. Of these, 2 would be on watch, and 6 on picket duty, leaving 17 men off duty. For these there are 16 cots, 6 feet by 2 feet 4 inches, arranged in tiers as shown, and a space at the right for the commander. Hammocks may be used instead of cots; they leave more space and are more comfortable.

At the upper end of the entrance gallery there should be a niche, with a loophole for a man on watch. (1917)

(*e*) A peculiar form of cover used—and described below—has some advantages, though it would apparently be rather difficult to construct in some soils, and the walls, if caved in by accurate artillery fire, would be apt to bury the men sheltered:

Another type of back trench suggested is located 15 yards only behind the firing trench, and connected therewith by a communication trench at every traverse. It is absolutely straight, 11 feet deep and only 16 inches wide; vertical sides revetted with poultry wire netting. Steps leading up from it to the communicating trenches. It is designed solely for shelter during a bombardment, and so narrow that shells will have little chance of finding it. Men can barely squeeze into it and stand in a single row.

(*f*) As the *reserves* are subject to almost as heavy artillery fire as the firing line and supports, the necessity for furnishing adequate cover for them is apparent. Due, however, to the greater latitude permissible in locating them, advantage may more often be taken of concealment and natural cover, which is usually strengthened, as time permits, to resist the heaviest bombardment.

The question of cover from fire for the reserves depends upon the distance in rear of firing line or the ability of the enemy's artillery in searching the ground on which reserves may be stationed. In any case, the possibility of being observed by aerial reconnaissance must be considered.

Shelters for the reserves intended for counter attacks. Rest shelters in the zones in rear exposed to the bombardment of heavy artillery, are or-

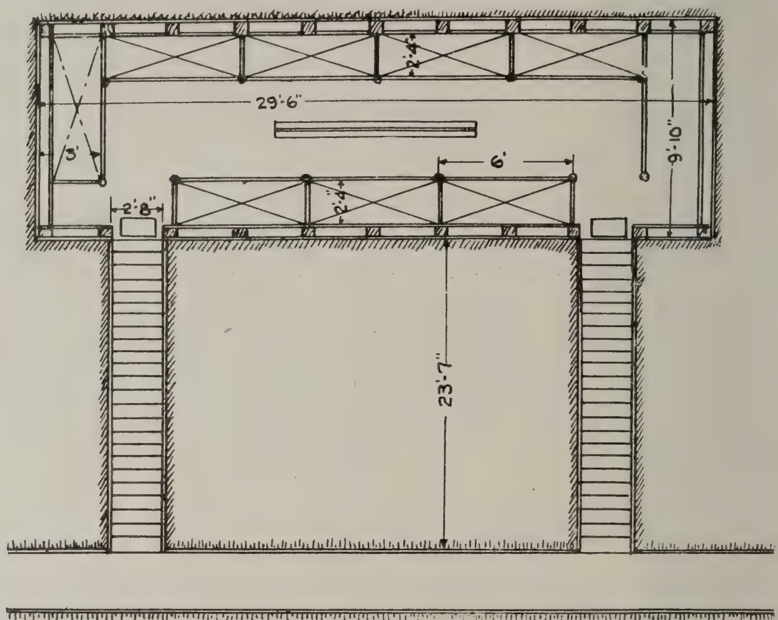


Fig. 32. Plan of a cave shelter.

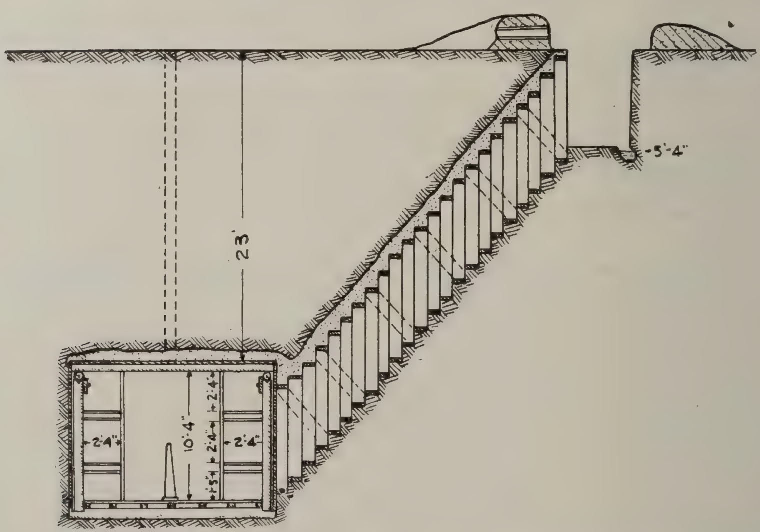


Fig. 33. Cross-section of a cave shelter and entrance gallery.

ganized in accordance with the preceding principles. However, it is possible to utilize more fully the natural features of the terrain such as steep slopes, sunken roads, quarries, etc.; cellars of houses; and concealment and protection of woods and forests. The construction can be made stronger as there is more time, more materials and workmen available, and a relative security due to invisibility. (1917)

(*g*) The practice of always providing the best cover for *telephone stations* is noted in all reports from the front:

In rear of the trench and close to it were numerous substantial splinter-proof huts for the men and one with a very heavy roof, well sunken below the ground, for the telephone station.

V. OBSTACLES.

The necessity of an obstacle as an essential part of any fortification has been recognized from the earliest days, when the wall or moat formed the chief reliance of the defense, down to modern times when all text-books on field fortifications illustrate and describe many different types of obstacles. Most of these types, however, seem to have given way in Europe to some form of *wire entanglement,* which has been used on such an enormous scale and under such varying conditions that a study of the experience in Europe with this type of obstacle must inevitably yield lessons of value.

(*a*) *Extent.* The entanglements are placed not only along the front of each army in a practically continuous line, but also in front of the second and third lines, and, at frequent intervals, running back perpendicular to the front, dividing it into sectors more easily defended in case a portion of the line is lost. In the attack, all positions captured are immediately consolidated and protected against counter-attack by surrounding them with suitable obstacles, which are either hastily constructed in place or are of the portable type and brought up with the attacking troops for this purpose. The quantity of wire required for constructing these obstacles is enormous, and it is believed that in preparing a line for a stubborn defense at least *100 miles of wire to the mile of front* must be provided. The supply of this material should not be left to chance, but should be arranged for beforehand, the same as any of the other necessary supplies of the army.

Everywhere wire entanglements are the chief form of obstacle used, and must be cut before an attack can be made.

Each detached trench was enclosed by a barbed wire entanglement,

low but substantial, about 25 feet wide, extending well around the flanks and rear. Extent of entanglement in relation to the trench development was unusual; it was necessary on account of the very short field of fire possible in dense woods in which no attempt at clearing had been made, except clipping low hanging branches, and felling a few scattered saplings.

The barbed wire obstruction was very formidable. In places 50 miles of wire to a mile of front was used, and around fortified places as much as 400 miles. (1915)

The section of front under consideration has been organized for a strictly passive defense. As comparative quiet has prevailed here for a long period, ample time has become available for perfecting details. Noteworthy is the great development of the obstacles, consisting of a belt of wire entanglement about 200 yards deep, arranged in rows parallel to the front, each row 5 yards wide and 40 to 50 yards between rows. The rows parallel to the front are intersected by other rows generally perpendicular to the front, thus dividing up the field of entanglement into a network of pockets or pens which serve to trap any of the enemy who may succeed in penetrating at any point. (1916)

(*b*) *Location and design.* The entanglement is almost universally located *close to the firing trench,* usually only 10 to 30 yards in front (instead of 75 to 300 yards as practiced prior to the European War); it is usually in *two belts* and sometimes more, each belt being from *5 to 10 yards wide,* and the belts placed about *20 yards apart;* in general, the practice is now to make it *wide rather than dense,* in order to avoid destruction by artillery fire, and for the same reason every effort is made to *conceal* it, and shelter it from the enemy's view (this may be done by placing it in either natural or artificial ditches or depressions in the ground, or behind low parapets thrown up to conceal it); its trace is *usually not parallel to the firing trench,* so as to prevent the enemy from using it to range on for firing on the trenches in the rear, and also in order to permit it to be enfiladed by machine gun fire from positions on the flanks or in the re-entrant angles. The height of the posts or supports used seems to be a compromise between our high and low entanglement, and is generally from *2 to 2½ feet.* The wire is *strung loosely* and many ingenious forms of spirals, hoops, and "crinolines" have been devised. A tendency to use *heavy wire,* in order to avoid its being cut with ordinary wire cutters, is noticed.

The liberal use of barbed wire is noted. The entanglements are quite wide, 25 to 30 feet; in some cases are formed in a double line. The wire

fairly light and easily cut. Stakes are about 2 feet high, and the wire is loosely strung. Entanglement is carried continuously along the front and around the flanks of the trenches.

. . . .

A low wire entanglement 15 feet wide lay close in front of the parapet not over 15 yards away.

. . . .

The wire net—a little further front here than usual—being 40 to 50 yards from the trench.

A low wire entanglement 15 feet wide lay close in front of the parapet the front of the fire trench and distant about 20 yards.

Ten to 15 yards in front of the line of trenches begin the wire entanglements covering a width of 50 yards (the greatest I have seen). In front of one company 500 trous-de-loup among the wire entanglements, and also some chevaux-de-frise.

At important points wire entanglement is used in twenty-foot wide belts in three rows placed at least 20 yards apart. (1916)

The outer edge of the wire was placed 30-35 yards from the parapet so as to prevent grenades thrown from there reaching the trenches. The distance was considered sufficient. (1916)

In front of the trench that we were in, were three lines: 1st, a line of chevaux de frise, then two successive lines of barb-wire, each about 10 yards wide and 2½ feet high; these barb-wire entanglements were about 20 yards apart. The line nearest the trench about 30 yards away. (1916)

Obstacles which are more than 30 yards in front of a fire trench are difficult to control by frontal fire in the dark. (P. 218 "Field Entrenchments"—Capt. Solano—1916)

Specially made wire much heavier than ordinary is used, in some places ⅛-inch thick; requires powerful cutters.

. . . .

Heavy wire, ¼-inch, is coiled into a ring about one yard in diameter, the rings are bound at intervals of ⅕ the circumference, each to the next in such a way that the whole can be pulled out to a wicket-like cylinder about 8 yards long. The closed rings can be easily transported and handled. At the front they are pulled out and bound further with barbed wire. This makes an effective obstacle.

Barbed wire is undoubtedly the most effective obstacle, especially if well concealed. The advantage of concealment, in addition to preventing ranging of the trenches in the rear, is also that working parties are enabled to repair nightly the damage or partial demolition of said obstacles.

The terrain between the trenches and in the vicinity is covered with bush and grass, which is allowed to remain, as it conceals the trenches, and the barb-wire, of which latter there is a great quantity. (1916)

The inside line is 25 to 100 feet from the firing crest. It is not always parallel to the crest, but sometimes arranged so as to be flanked by fire. (1915)

(*c*) *Hasty erection.* The necessity of erecting entanglements rapidly, in consolidating a position gained in the attack, or of repairing them without noise in close proximity to the enemy, as well as for closing openings left for the use of one's own troops, has developed many skillful methods of hasty erection, and many types of portable obstacles. Some of these are described below:

Drill in setting up hasty wire entanglements. The wire is formed into a series of panels each 7′ 8″ long, fastened between rough posts, about 4 feet high, and pointed at the lower end. The form of panel is shown below:

Eleven of these panels are made into a continuous web, and wound into a roll for use. To make an entanglement the first roll is unwound along the desired line and the posts driven into the ground with a heavy mallet. Then the second roll is unwound behind the first, with its odd-

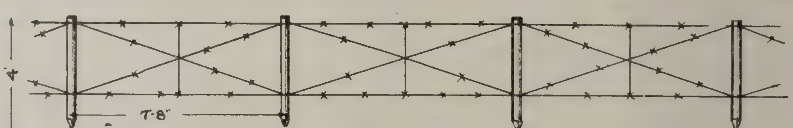


Fig. 34. Wire web for hasty erection.

numbered posts placed adjacent to the first, second, third, etc., posts of the first line while the even numbered posts of the second roll are driven midway between the posts of the first line, and far enough back to stretch the wire into a series of equilateral triangles with the panels of the first line as their bases. Another roll is then unwound, and its posts driven alongside those forming the apexes of the triangles to complete the entanglement. A few men can erect this obstacle very rapidly in ordinary earth.

The close proximity of the opposing trenches precludes the construction of the usual forms of entanglements, even at night as the noise made in driving stakes would invariably draw fire. To meet this condition a number of expedients are practiced. If the lines are not too close, entanglements can be constructed under cover of darkness by screwing iron posts or stakes into the ground and stretching barbed wire between them in the usual manner. The stakes used for this are round iron about ¾ inch diameter, bent into a corkscrew at one end, and having two or three loops along their length for attaching the wire. In ordinary ground such stakes can be screwed in for a firm hold and without noise. When the lines are too close for this procedure to be followed, portable obstacles in the nature of Chevaux de frise are employed. These are made up in the Pioneer Depots, brought forward through the trenches and

simply tossed out in front of the trenches, either by day or night. A variety of frames are used for these portable Chevaux de frise, some being in the form of a sawbuck, others tripods, a common form of the latter being three iron rods fastened firmly at their centers. By bending out the rods the diagonals of a cube about 2½ feet on the edge are formed. Wire is then stretched between the points of the rods and the frame is ready for use. These affairs are called "hedge hogs." The frames are invariably of steel, either light angle irons or plain rods, with loops or notches for holding the wire. The idea is precisely the same as the tripod and trestle obstacles first used by Japanese and Russions in the Mukden position. (1916)

Wooden or iron posts were used. The iron posts built for the purpose were about ¾ inch in diameter and pointed. The first has four loops; the upper two for holding the wire, and the lower two close together near the lower end; in the lower two, iron rods about 1½ feet long were inserted. The posts are buried in the ground about 30 to 32 inches, and the earth well tramped, the rods through the lower loops preventing the posts from being pulled out. There are usually three rows of posts set in quincunx order about 10 feet apart. (1915)

The method of constructing high wire entanglements, as shown in Manual of Field Engineering, with its posts set 3 feet 6 inches or 4 feet above ground, and the barbed wire strung thereto, has been abandoned, owing to the fact that first, the posts are altogether too conspicuous and make excellent range marks for the enemy; second, as all repair work has to be carried out at night within close range of the enemy's trenches, absolute silence must be maintained; consequently hammering or driving posts is out of the question.

Various substitutes for posts have been tried with more or less success. Three-sided triangles constructed with strong limbs of trees, firmly lashed together, have been prepared in rear of trenches and carried and set out in front of the firing line at night, at intervals of about 15 feet. These are fastened to an anchorage placed in the ground and the barbed wire well laced between and all over them.

Also limbs of trees about 8 or 10 feet long, crossed at the center and similar to the spokes of a wheel, have been constructed and erected in the same manner.

Any light, portable and strong support for a barbed wire obstacle is acceptable and of value.

Portable obstacles may be usefully employed for the temporary closing of roads, gaps in wire entanglements, etc. (P. 218 "Field Entrenchments"—Capt. Solano, 1916)

(*d*) *Destruction.* Entanglements are most effectively destroyed by artillery fire from *large caliber* guns using high explosive shell, or by means of similar charges of high explosive in bombs or torpedoes thrown from *trench mortars:*

As long as a bombardment is confined to trenches and approaches it

is not considered serious, but when the shells begin to concentrate on the wire entanglements the defenders get ready to meet an attack.

. . . .

Artillery fire is chiefly relied on to cut the wire, and shells from the trench mortars with their big explosive charges are reported to be very efficient for the purpose.

The destruction of wire entanglements by Artillery fire is very difficult. It would seem that this should not be so difficult, but I have looked over wire entanglements which have had a large number of shells exploded in them, and it is surprising what little damage was done. Shells from 3 inches up to 6 inches did very little damage. Their 6-inch shell is not nearly so powerful as ours. The hole in the entanglements made by a 12 inch mortar is about 25 yards in diameter. (1916)

VI. MACHINE GUNS.

The effect on field fortifications of the increased use of the machine gun in modern warfare is mainly in the direction of rendering more important the knowledge of the advantages and limitations of this arm, together with a knowledge by all combat officers of *when and where to use machine guns,* and *how to make the simple and necessary arrangements for their effective use* when brought into action.

The *general principles* affecting their use may be stated as follows:

(*a*) The necessity of *concealing all machine-gun positions,* so as to avoid their destruction during the artillery bombardment preceding the attack, and also in order to introduce the element of surprise when they are finally unmasked and placed in action. (This generally forbids the use of heavy overhead cover for the gun and detachment when firing.)

(*b*) *Ample cover* against the heaviest artillery fire must be provided for the personnel, and gun and ammunition, *when not in action.* (This must be close to the firing position.)

(*c*) Provision of many *alternate firing positions,* in order to avoid disclosing the most important locations prior to the main attack, and thus avoid their destruction by the enemy's artillery.

(*d*) The *concentration* of all machine guns on the first line *must be avoided,* many being placed in rear so that they can be brought into action successively as the attack develops, and thus prevent their early destruction during the artillery preparation.

(*e*) *In the attack,* machine guns follow the attacking troops closely, so as to be available for resisting the counter-attack.

The *various locations for machine guns* which seem to be in general use by the armies in Europe, are:

(*a*) *In front of the first line trench:*

1. To enfilade obstacles;
2. To bring an enfilade fire on attacking troops while the trenches are still under artillery fire.

(*b*) *In the first line trench:*

1. Located in the re-entrant angles, to bring enfilade or oblique fire along the adjacent front;
2. Located on the flanks of a single trench to bring enfilade or oblique fire along the front, and also to flank the intervals;
3. To sweep gaps left in the obstacles.

(*c*) *Behind the first line trench:*

1. To enfilade one's own trenches in case of capture, especially the approach trenches;
2. To bring a fire on the enemy's flank in case he should pierce the intervals between "supporting points," or any other part of the line;
3. To economize men in garrisoning the "redoubts" of the second or third line.

These principles are exemplified in nearly all reports from Europe, some of which are given below:

In siting machine gun emplacements, the following ideas should be developed:

To bring to bear powerful enfilade or oblique fire on the attacking enemy at effective infantry range.
To give flanking fire to supporting works.
To sweep gaps left in a line of obstacles.

The two great aims should be (a) to surprise the attacking enemy, and (b) to conceal the emplacement and give effective shelter to the machine gun detachment. (P. 52 "Knowledge for War"—Capt. Lake, 1916)

The two machine guns of this battalion were at the two front corners of the position, apparently arranged to cross-fire in front.

Machine guns are placed in re-entrant angles giving an enfilade fire along the adjacent lines or on the flanks of a single trench. They are also placed when the ground permits above the trenches. They are kept in deep holes in the trenches, and are brought up and placed in position when needed. Sometimes quite in the open on the lip of the trench. When the ground permits, machine guns are placed in concealed positions about 30 yards in front of the trenches to break up an attack that is

undertaken while the trenches are under enemy heavy shell fire and while curtain fire is being used to keep back the reserves. (1916)

About every third traverse contained a machine gun emplacement. These were dug into the traverse and were entered by a narrow, winding passage way in rear. The head cover was about one foot thick. The emplacement consisted of a room about 6 feet wide and 8 feet deep, with a loophole about 8 inches high and 3 feet long, which could be closed by a board. When the machine gun (Colt) was used in these the muzzle of the gun was held about 6 inches back from the interior of the loophole so that the flash would not be visible, particularly at night. (1917)

Machine gun emplacements should be on the flanks of the position and under cover as much as possible. Avoid unmasking too soon, so as not to expose to premature destruction by artillery.

In order to have some machine guns available to meet the infantry

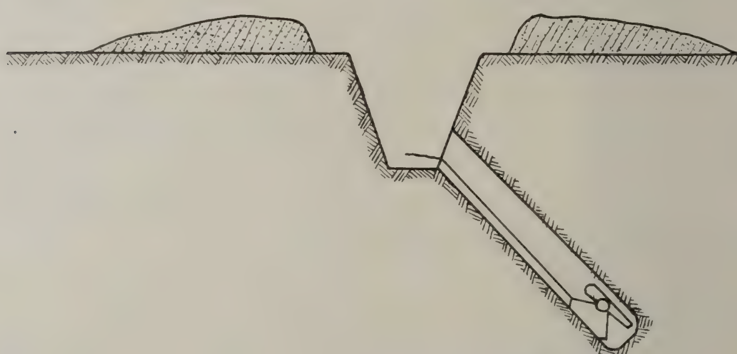


Fig. 35. Section showing cover for machine guns.

assault following the now customary heavy artillery preparation, machine gun recesses are built under the front parapet with bomb-proof roofs. On one or both sides of the recess are built firing platforms at proper height upon which the machine guns are quickly placed to fire over the bank the moment artillery fire ceases and the infantry assault begins. (1916)

For the protection of the machine guns themselves, special inclined shafts are located at intervals under the parapet into which the machine guns are lowered by ropes and from which they can be quickly drawn when the emergency arises (see Fig. 35). (1916)

The location M, Fig. 36, on the first line, and A and B on the approach, will give an effective flank fire in case of a hostile penetrating attack.

. . . .

Principles of the employment of machine guns.

1. The personnel and materiel should be protected from fire as much as possible.

2. In order that the guns may be available at the moment of attack, it is indispensable that they survive the bombardment. Their protection must therefore be specially provided for, by employing all of the following means:

(a) Placing them under shelter.
(b) Making their emplacements invisible.
(c) Placing them in echelon.

3. Casemates must be used only when they cannot be seen by the enemy, such as on the reverse slope, in woods, in villages, etc.

4. The great importance of making the machine guns invisible necessitates the construction of firing emplacements outside the shelters, but close enough so that the guns can be put in action with the least possible delay.

5. The firing emplacement may be protected by a light roof with very slight height, or it may be entirely without overhead protection. The emplacement may consist simply of a pit in the open field, situated in

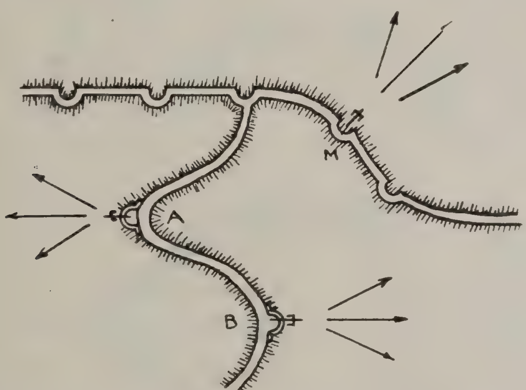


Fig. 36. Location of machine-gun emplacements.

front, or in rear of the parapet, and connected with the shelter by an underground passage. The machine gun should be placed in action at the last moment. It may be simply placed on the edge of the pit without any protection, or preferably it should be covered by a light shield, or a low parapet joining the natural slope of the ground with a gentle slope. The pit should be carefully hidden and will usually not be discovered by the enemy. Emplacements of this nature are frequently employed in rear of the first lines.

6. When the trench is situated on the reverse slope, machine guns should be emplaced in concealed pits in front of the trench, and connected with it by underground passages.

7. The requirement of invisibility makes it necessary to conceal all the approaches to the firing emplacements by making them underground, and to increase the number of emplacements so that it will not be necessary to fire daily from those to be used in case of an attack.

8. The emplacement of too many machine guns in the first line is

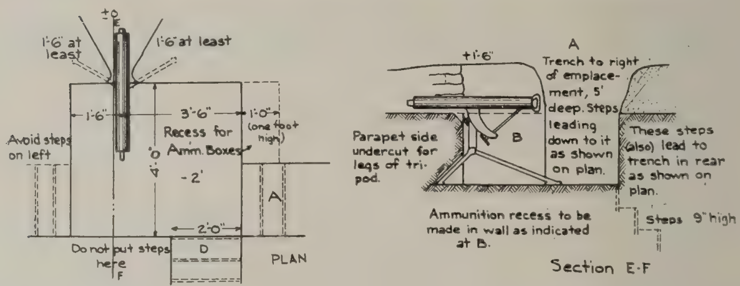


Fig. 37. Machine-gun emplacement. (From P. 53 "Knowledge for War."—Capt. Lake, 1916.)

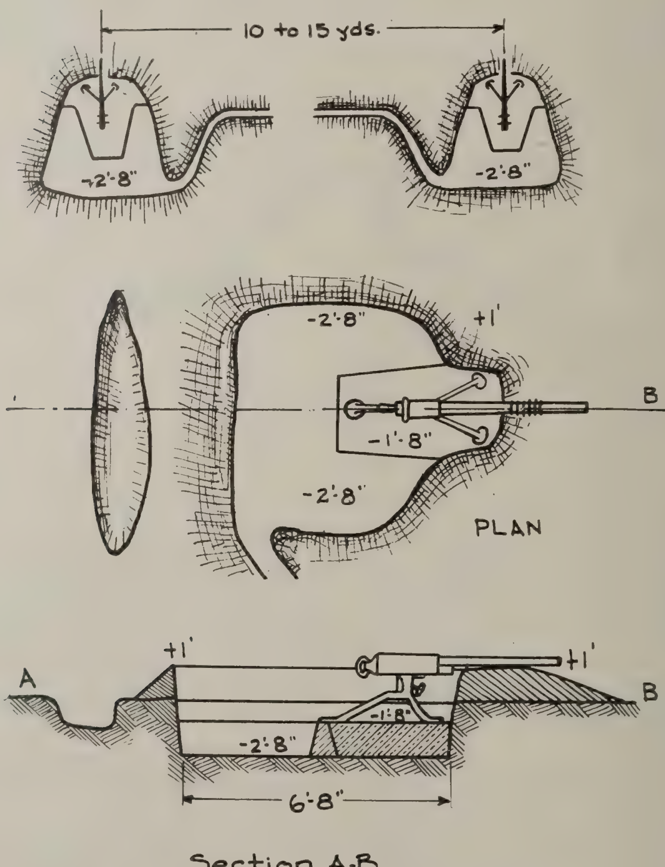


Fig. 38. Hasty cover to shelter machine guns in an attack. (1917)

dangerous; in order to stop an attack they should be echeloned to the rear. In favorable terrain, flank fire should be provided, to mow down the attacking lines as they push forward. Therefore, the available machine guns should be distributed between the first line and the terrain in rear, with each emplacement prepared in a manner suitable to the terrain and object in view. (1917)

Some types of machine gun emplacements developed in the European War are illustrated or described below:

A Maxim on tripod mounting requires a platform of earth about 4 feet square, and sunk about 12 to 18 inches. On the right-hand side and in rear of the platform a trench 2 feet wide may conveniently be cut to a level 3 feet below that of the platform, and leading to the detachment shelters and the general communication trenches. Since machine guns

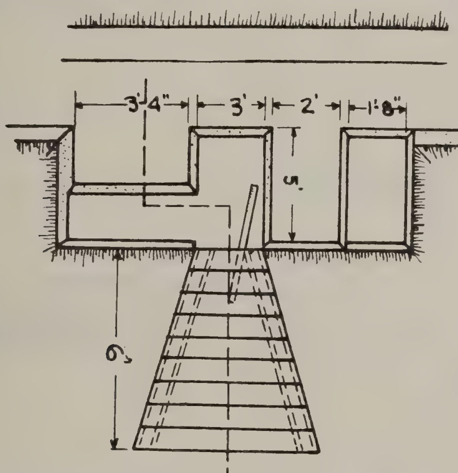


Fig. 39. Plan of machine-gun emplacement, with movable light head cover.

are usually employed for flanking or enfilade fire, good traverse protection is necessary on the exposed flank. (P. 217 "Field Entrenchments"—Capt. Solano, 1916)

An emplacement without overhead cover may consist of a simple platform constructed on the edge of the trench.

. . . .

An emplacement with movable light head cover and low command is shown in Figs. 39, 40, and 41. The emplacement is made in front of the trench, with recesses and benches on each side for the personnel and ammunition. The head cover is hinged and is made of corrugated sheet iron, covered with earth, blending exactly in color and appearance with the front slope of the parapet. By raising the head cover with a lever, a loophole 3 feet by 1 foot is opened, which permits an effective fire. (1917)

VII. ARTILLERY.

The influence of artillery on the conduct of modern warfare is so marked that practically all observers in Europe are continually referring to the importance of this arm. It is believed that the principal reason for this importance is because it is the only weapon which can cope with the defensive power of modern field fortifications. In fact, the art of field fortification has been practiced only since the introduction of mobile artillery, and as the

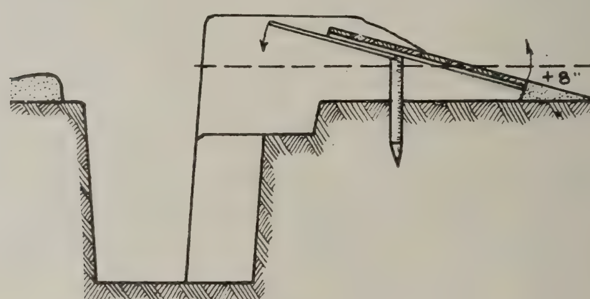


Fig. 40. Profile showing head cover lowered.

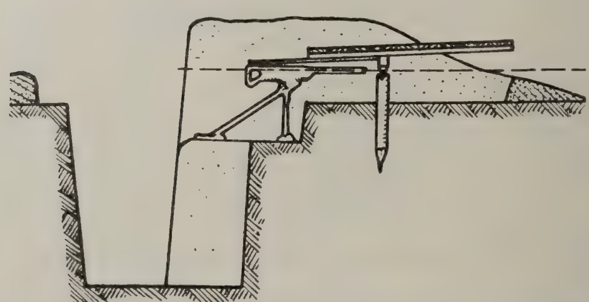


Fig. 41. Profile showing head cover raised, machine gun ready to fire.

caliber and range of the latter has been increased a corresponding change has inevitably occurred in the types of field works constructed.

(*a*) The rôle of artillery in the present war in Europe, so far as it affects the design of field fortifications, may be gathered from the following quotations:

It may be positively stated that strong field fortifications, heavily protected by wire entanglements, with a fairly efficient body of troops occupying them are impossible of capture by Infantry, unless the attack is prepared by heavy and effective Artillery fire. (1916)

Attack. No attack is possible until after an intense and effective artillery preparation, which has for its objects:—

(a) To destroy the enemy's barbed wire.
(b) To disintegrate and destroy enemy's trenches and dugouts, and destroy or annihilate their defenders.
(c) To prevent or at least to interfere with hostile artillery action.
(d) To prevent the passage of the enemy's reserves by curtain (barrage) fire.
(e) To destroy the machine guns wherever they can be located.

. . . .

Defensive Action. The experience gained in recent attacks on the Eastern Front as well as on the Western Front makes it possible to state today that an attack on a line of trenches should be successful if it is well prepared by an artillery *which is unhampered by considerations of ammunition supply.*

Under the rain of projectiles of all calibers which disintegrate or destroy the trenches, the dugouts, and the barbed wire, and which annihilates the defenders, the defense of a line which can be seen by the enemy becomes almost impossible. The attack can be easily delivered and the position where the enemy's trenches existed can be occupied almost without firing a rifle shot.

But the artillery of the defense can make the enemy pay very dearly for his success even if it cannot make that success ephemeral. (1917)

(*b*) The necessity for *large caliber mobile* artillery was first appreciated by the Germans, who opened the war well supplied with guns, howitzers, and mortars of calibers up to 12 inches, which were capable of accompanying the army in all ordinary movements. This equipment, it is believed, contributed materially to their early successes, and the other belligerent nations hastened to furnish themselves with the needed material. All the armies are now equipped with mobile artillery of 9, 10, 11, or 12 inch caliber, and most of the destruction of field fortifications is effected with guns of a caliber of 6 inches or upwards.

The 3-inch gun, forming the major portion of the mobile artillery with most armies before the European War, has proved to be ineffective when used against modern field fortifications, and is apparently now used almost exclusively against troops in the open.

In the present European War it is reported that the heaviest bombardment of the 3-inch field artillery is ineffective against trenches carefully organized.

The 12 inch pieces were carried along with the advancing army, and were used against a strong supporting point, not a fort. (No. 29)

It is stated that the 12 inch mortar can be emplaced in two hours. It

should be possible to shift a battery of these at least 30 miles on motor trucks going 8 to 10 miles per hour, and make it ready to fire in one night.

(*c*) The great range of modern artillery, especially the larger calibers, permits it to be placed at such a distance from the front that it is usually screened from the enemy's direct view, and would consequently be fairly safe from his artillery fire without any cover or shelter at all, were it not for the modern use of aircraft in locating targets and controlling artillery fire from a distance. This use of aircraft which has developed in Europe, has made it necessary to use every effort to *conceal the location of batteries from observation from the air.* The amount of concealment necessary should depend on the aerial equipment of the enemy.

Several similar batteries were noticed at other points along the road, all being in the forest where they were screened from aviators.

. . . .

On reaching the right flank emplacement the officer guiding us said "there is the field gun," pointing to a careless looking pile of straw scarcely 25 feet away. No gun was visible until the soldier lifted off several sheaves of straw. The gun, and every part of its carriage was entirely buried in straw, not placed regularly but tumbled over the piece in a more or less careless manner. Considerable straw was lying about in front of the splinter-proof shelters and field magazines, which were located alongside the guns so that the effect of the whole as viewed from a distance was that of an irregular lot of straw piles. The guns were spaced irregularly both as to intervals and as to line, varying from 20 to 40 yards apart by the shortest line.

The greatest care is taken to conceal the gun from aircraft. The upper layer of earth, bricks, dust, etc., is made to conform exactly to existing surroundings. Gun emplacements are photographed from their own aeroplanes at a low altitude, and any shortcomings in the way of invisibility are thus disclosed and corrected.

. . . .

The men of the ——— captured near ——— were in position with a single gun within 600 yards of the enemy's trenches and stayed in one position for 3 months without being discovered. All prisoners attributed the comparative immunity of their gun positions more to their supposed invisibility from the air than to the actual shell-proof properties of their earthworks.

. . . .

Everyone is forbidden to approach a battery except those who are connected with it. All paths and tracks which would show up in photographs are now studiously avoided. As soon as a battery is located it goes to an alternative position. The enemy's batteries were fairly easily detected on photographs on account of the paths and tracks near them.

Vehicles, not even caissons are now not allowed near batteries. There is only one approach to each battery.

In order to prevent flashes of guns in action being seen, flash-screens have been constructed about 200 yards in front of each battery. They are made of sacking tacked on light wooden frames, and are about 12 feet high. In general appearance they are not unlike the canvas screens put up around small circus grounds in the U. S. (1916)

The batteries were generally a mile or two in rear of the line of trenches. The guns themselves had but little direct protection, usually a low parapet. They were located behind hills and their position was concealed as much as possible, so that aeroplanes should not locate them. This was accomplished by scattering, by covering the guns in the day time when not in use, with canvas, branches, planks, etc., and at times by planting small trees or limbs. The location was often changed. Dummy batteries of logs, of old wagons, etc., were often used. (1915)

As a rule no special effort was made to conceal batteries from aeroplanes. The enemy apparently had few aeroplanes, and did not use them for conduct of fire. When woods or buildings were available, the gun positions were protected by the woods or by putting them under sheds, but this was unusual. Limbers and horses were kept in the open or in the woods and villages, depending entirely upon circumstances. Ammunition trains were ordinarily kept in villages. If a battery had been located by the enemy's batteries through aeroplane observation, this battery would be moved 200 or 300 yards to the right or left. I saw some very accurate, though slow, firing done by the enemy against a set of emplacements which had been occupied on the preceding day by one of our batteries. The latter had been moved about 300 yards to the right during the night. (1916)

(*d*) As the efforts at concealment are seldom perfect, the possibility of the position being discovered by the enemy's aerial observers must be considered, and other means of protection provided; these usually consist of *ordinary gun pits,* with *bomb-proof shelters* for *ammunition* and the *gun crew when not firing.*

The amount of cover provided under varying conditions may be gathered from the quotations below:

A battery of two 6 inch howitzers was located to one side of the main road on the steep reverse side of a wooded slope.

. . . .

The guns were located in open pits, with ammunition stored in bomb-proof chambers excavated in the slope. Men were living in ordinary hutments near the battery, but had substantial bomb-proofs into which they could retire in case of need.

. . . .

Several hundred yards to the left of the howitzers were two field

gun batteries located on the reverse slope of a gentle rise. As these guns were in perfectly open ground their emplacements were well dug in, with deep and narrow connecting trenches between the gun emplacement and the splinter proofs, latrines, and telephone stations.

These 3 inch guns are placed back of a gentle slope in the usual gun pits, and when not in use are covered with straw to conceal them from flying machines.

. . . .

The 8.4 inch howitzers observed were back of a very gentle slope and were concealed by pine branches. They were about 9,000 yards from the enemy's positions.

. . . .

The 16.8 inch mortars used against the permanent works were in accordance with the above principle, mounted at a distance of about 9½ miles from the nearest fort. A branch railroad had to be built to carry these mortars and their mounts to the positions chosen. They were installed in pits 15 feet by 20 feet by 6 feet deep, and about 100 yards apart.

Field artillery pits were generally simple, the guns being placed behind woods or elevations.

. . . .

The men were given protection by trenches and shelters when not firing, and they were made generally as comfortable as possible. The observation stations were in houses, or concealed field works at some high convenient point. (1915)

Artillery ordinarily entrenched, though I saw several cases where no entrenchments were dug. Usually in going into position they first dug a semi-circular ditch for the trail, so as to obtain the maximum elevation. This earth was thrown to the front for a parapet, holes were dug on the sides for connoneers, and this, with the other earth, formed a fair parapet, leaving the gun on the natural surface. But there seemed no fixed rule about this, and I have seen all sorts of combinations. Deep trenches were often dug near the battery where cannoneers could take cover in case of necessity. The Battery Commander usually has a hole dug in the ground, with overhead cover, and a good view to the front. (1916)

(*e*) It is not the intention to discuss in this article the many developments in the use of artillery brought out by the European War, except as they influence the design or location of field fortifications, but it is believed that *the assignment of mountain guns of 1.5 inch caliber to infantry battalions*, with the attachment of artillery officers and enlisted men to these battalions to serve the guns (which is already an accomplished fact in one of the belligerent armies) is such a radical change that if it has not already affected the design of field fortifications, it is bound to do so ulti-

mately. For that reason, the extracts given below are included in this article:

The attachment of guns directly to the infantry has been brought about by the following considerations:

(a) By the need of a gun light enough to follow up both with fire and by a forward change of position any advance of the infantry. Experience has shown that communication so often breaks down at critical times that it is then impossible to get word to the divisional guns at the right time. Furthermore, divided authority always involves loss of time; and the presence of guns directly under the orders of battalion commanders will avoid any loss of time or any difference of opinion as to the need for guns.

(b) By the need of a gun directly controlled by officers in the front trenches which can be brought to bear on machine guns which the divisional artillery have failed to hit or failed to see.

(c) By the need of a gun ready at hand at all times to break up sudden attacks or counter attacks.

(d) By the gradual development of the idea of decentralization by which subordinate commanders are given the means necessary for independent action; and, having been furnished the means, are simply told what the plan of the higher commander is and then told to "help out." During present-day instruction, officers are continually told that "An order isn't an order—it is an indication.

This decentralization makes it imperative that the battalion commanders of infantry be given every possible means for offensive and defensive independent action. Some sort of artillery being necessary for such action, the attachment of guns to infantry units referred to, naturrally followed.

It is believed that if this assignment of artillery directly to infantry proves to be successful, it will be not only of the greatest tactical importance, but may also effect a far-reaching change in the materiel assigned to the artillery itself.

The great fire superiority of the heavy field gun of 4.2 inch or similar calibre over the ordinary light field gun has been demonstrated repeatedly in this war; and the only reasons for the retention of the light field gun lie in its comparative mobility, rapidity of fire, and length of accuracy-life. If by assigning to the infantry a still lighter, more rapid and more durable gun the characteristics of the light field gun have been diminished in importance, this step may result in the heavy field gun becoming the chief weapon of divisional artillery and in the consequent gradual elimination of the light field gun. (1916)

In the attack of a position organized for defense, whether in trench warfare or the war of movement, troops which have taken the first enemy

lines often hurl themselves against a second line which, although it has also been demolished by the artillery, is still able to stop the infantry advance by means of machine guns. These machine guns, placed in hidden block-houses, and having either escaped the fire for adjustment of the artillery, or else been kept hidden with their gun crews in dugouts, are at the last moment placed in emplacements previously determined upon.

Against such machine guns the infantry can do nothing and the artillery is so far away that there is no opportunity to ask for its fire. Communication with the artillery is, on account of the hostile curtain fire, so difficult that it is impossible to ask for accurate fire delivered rapidly. *It is necessary that means to destroy such machine guns shall be given to the infantry themselves.*

Bomb-throwers which are provided for trench warfare have so little accuracy that they cannot be used for this purpose. It would seem that if light pieces of artillery served by gun crews which can carry them forward are furnished, when the first waves of the assault have carried the first of the enemy's trenches, it will be possible to destroy those machine guns which have escaped the artillery preparation and which afterwards have disclosed their positions in the second line. For this reason several attempts have been made during large attacks to have the infantry accompanied by 1.5 inch guns, and 2.6 and 3.2 inch mountain guns.

The expected results have not been attained. These guns have a flat trajectory, especially the 1.5 inch gun at short ranges, and it is necessary to place them in uncovered positions outside of the trenches. The cannoneers make very visible targets, which are easy to hit. It has frequently happened that they have been put out of action before they have been able to open fire.

The 2.6 and 3.2 inch mountain guns present great difficulty on account of ammunition supply. In the terrain full of all kinds of obstacles one man can carry only one 3.2 inch projectile weighing 18 to 20 pounds or one 2.6 inch cartridge weighing 13 to 15 pounds.

As an accompanying infantry gun, there is required a very short light howitzer which can be transported as easily as a machine gun, and can be fired from a trench or a shell hole or a ditch.

The 1.5 inch and 1.9 inch guns seem suitable as to calibre; and a careful study of the problem brings us to the conclusion that these are the calibres to be adopted.

The 1.5 inch fires a projectile weighing 1.1 to 1.76 pounds, and the 1.9 inch fires a projectile weighing from 2.2 to 3.3 pounds. Such a gun should have a low initial velocity because the pieces will be rifled howitzers which can fire a projectile with a very thin wall and a large percentage of explosive, 50 per cent to 60 per cent at the least.

These howitzers will be laid directly or by means of periscopes, and the powder charges will be varied so as to obtain ranges of between 200 and 1000 yards.

Ammunition supply will be easy, because one man can carry 15 to 20 1.5 inch cartridges, and 10 to 15 1.9 inch cartridges. Two men carrying ammunition boxes can carry much more.

Such pieces may either be carried by hand disassembled like machine

guns, or, according to circumstances, they may be hauled on wheels. They may be fired either from tripods or from wheeled mounts. They must be arranged so that enough rapidity of fire may be obtained to compensate for the small calibre.

The gun crews organized from the artillery of the infantry should be organized so that the pieces may be marched either singly or in sections of two. They should be a part of the infantry regiment and be assigned one to a battalion in the same way that machine gun crews are organized.

Use in the War of Movement. Light howitzers will be of as much if not more value in the war of movement as in the war of trenches. For in the attack of positions the infantry will meet the same obstacles and the artillery will have neither the time nor the means to prepare the attack as well as in the trench warfare. The effect of the light howitzer will probably be more marked than in trench warfare, because the enemy will not have time generally to prepare casements for his machine guns. (1917)

VIII. OBSERVATION.

The ability to command a view of the immediate foreground is an essential of every field fortification, not only so as to bring an effective fire thereon, but also in order to discover the enemy's disposition, observe his movements, and note the effect of one's own fire.

Means of observation must be supplied for the following:

(*a*) Sentinels, or small detached posts, in front of the trenches;
(*b*) Sentinels in the trenches;
(*c*) Commanding officers of all units;
(*d*) Artillery observers.

The practice in Europe as to the arrangements considered necessary for insuring this observation, appears to be about as follows:

(*a*) *Sentinels in front of the trenches* are in "listening posts," usually consisting of a short trench provided with "splinter-proof" overhead cover and loopholes, all well concealed.

(*b*) *Sentinels in the trenches* are sometimes stationed in "lookout posts," somewhat similar to the figure below, but usually they are provided with nothing more than a periscope, with which they can observe to the front from any point of the parapet without exposing themselves to hostile fire.

An easy type to improvise is shown in Fig. 42. Two steel rails, 2 feet 8 inches in length are placed horizontally at a few inches apart parallel to the trench. Upon these is constructed a roof to protect against the burst of projectiles. A frame protected by sandbags covers the rear. (1917)

(*c*) *Commanding officers of companies* are usually provided

with sheltered stations, called "combat posts," similar to that shown in Fig. 42 above. These are at points especially suited for observation in the firing trenches, or preferably in the "supervision" trench. Observation posts for *commanding officers of higher units* are, ordinarily, farther to the rear; and trees, ruined houses, or high ground are utilized whenever available, always screening and concealing the post from the enemy's view, and providing as much cover as is consistent with certain concealment.

(*d*) *Observation of artillery fire*, when not carried out by aircraft, is effected by special observers posted in stations similar to those just described for commanders of higher units. Often these observers are posted in the infantry trenches, not only to be able to observe the fire from the batteries more efficiently, but in order to keep in closer touch with the infantry. This cooperation be-

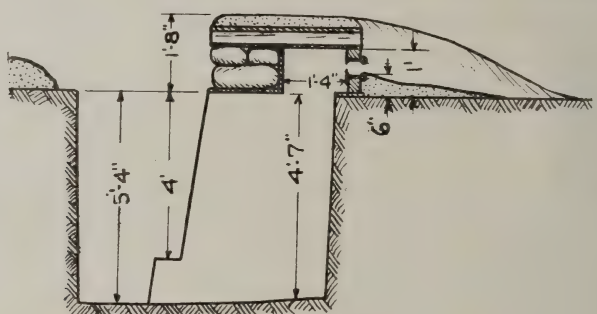


Fig. 42. Observer's post of rails and sandbags.

tween the infantry and artillery is marked—in many cases the only observation of artillery fire being done by infantry officers in the trenches, who transmit the information thus obtained to the artillery by telephone. In one of the belligerent countries instruction in the observation of artillery fire is now given all young infantry officers when undergoing training. As one authority states:

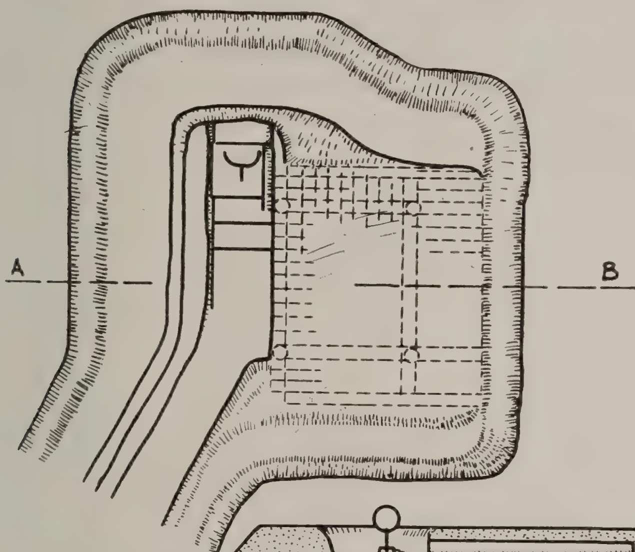
> The greatest problem now in the attack is how to inform the artillery accurately and rapidly about the points reached by the infantry. Observers must accompany the attack and send information back to protected telephone stations, located as far forward as possible.

(*e*) The use of many different types of *periscopes* for all observers, including sentinels, is general, and a certain number are issued to all organizations as regular equipment. Their use from deep bomb-proof shelters is noted, doing away with the necessity of sentinels in the trenches during heavy bombardments.

(*f*) In order to permit *observation to be continued at night,* searchlights, flares, and illuminating bombs or grenades, are required, and have been used extensively.

A typical searchlight shelter is shown below.

The information in reports from the front as to the details of observation stations is rather meager, but the following extracts indicate that *concealment* is considered of *first importance,* and



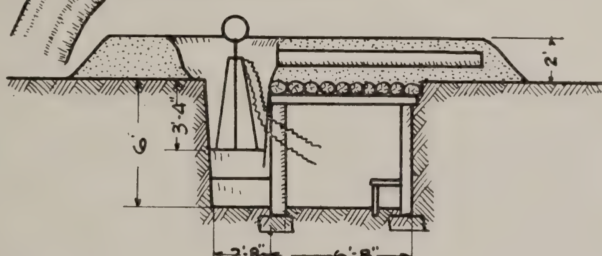


Fig. 43. Plan of a searchlight shelter.
Fig. 44. Searchlight shelter, cross-section AB.

that cover is quite secondary, and only furnished where it can be done without sacrificing invisibility.

The defensive works consist first of a line of listening posts pushed 50 to 100 yards to the front, and 150 to 200 yards apart. These posts are for a couple of men, well dug in with overhead cover and wire entanglement. They are, in effect, little block houses, and are so named by the troops. They are connected with the fire trenches by communicating trenches leading through the main wire entenglement.

A number of observation stations were maintained along the parapet, some open and some covered.

Heretofore it has been found necessary to maintain a few men in observation stations along the parapet to observe the enemy's movements, even during the severest bombardments. These observers naturally incurred heavy casualties which it is now sought to obviate by the use of periscopes operated from the bombproofs themselves. Each bombproof has 3 periscope tubes, similar to those used on submarines, one at each end and one in the middle (see Fig. 45). (1916)

Observation in front of the first line. The small posts, or listening posts of from 1 to 8 men are placed in rifleman's pits, shot holes, organized shell craters, or in short semi-circular elements of trench, connected

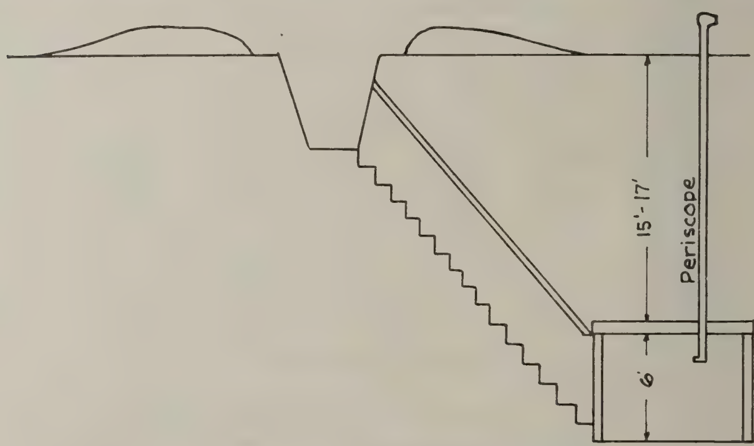


Fig. 45. Section of deep bombproofs.

with the first line by sap or low mine gallery. Their protection is assured by their invisibility.

. . . .

Observation on the first line. This is effected by lookout posts organized preferably at the salients where the view is more extended. These posts give a view over the enemy's first line. They are provided with periscopes, with range finders, and large scale maps.

. . . .

Concealment of lookout posts. It is necessary to conceal these posts by all possible means. Observation is carried out under good conditions only when it is done without the knowledge of the enemy. The posts should preferably be constructed on the right of a traverse, and in an excavation in front of the trench wall. (Fig. 46). (1917)

Artillery Observers are posted in the firing trenches and in close touch with the infantry sector commanders.

On the summit of a hill there was an artillery observation station consisting of two casemates; these were provided with a firing slit. One casemate was occupied by the artillery observing officer and a telephone operator, the latter connecting with central reaching to all batteries. Although the station occupied the highest part of the hill there was no conspicuous peak or lines to draw fire. It was moreover well screened with trees and brush.

Even the barrels of the scissors telescope in the station were wrapped in green moss for better concealment. No precautions for concealing such vital points of defense as observing stations are considered superfluous.

Searchlights and star bombs have become absolutely necessary to meet the constant night attacks by armies in both theatres of war. (1915)

The construction of simple flare lights of long life shielded on the defenders' side should be practised.

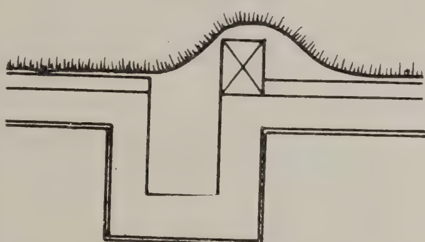


Fig. 46. Location of an observer's post.

IX. MISCELLANEOUS REQUIREMENTS.

(*a*) *Care of Wounded.* Very little data was obtainable as to whether or not it was the general practice to provide covered dressing stations close to the first line. It is believed, however, that ordinarily they were located from one-quarter to one-half mile in rear, and that at least one approach for each sector of the defense was prepared with easy bends for carrying litters, in order to be used when necessary for evacuating the wounded.

A short litter for use in the trenches has been improvised. It is designed to carry a wounded man in a sitting position so that he can lean against the rear bearer.

(*b*) *Latrines* were always provided near the firing trench, even for trenches only occupied for comparatively short periods. Some types in use in Europe are illustrated or described below:

Latrines are at the ends of small branch trenches and consist simply of a deep hole in the ground covered at ground level (bottom of trench)

with a plank platform in which is a hole a foot or so in diameter with a cover. (Note: This is the standard type in use all over China in small villages and country districts.)

(*c*) *Drainage* is of utmost importance and is emphasized in all reports from Europe. It should be considered when first laying out the trenches, as a slight shifting of the line at that time will often make the drainage much simpler, without appreciably affect-

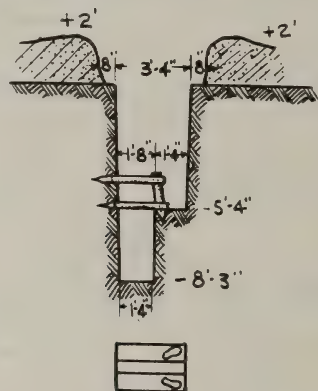


Fig. 47. Latrine without overhead cover.

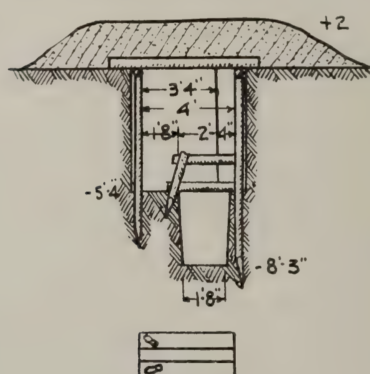


Fig. 48. Latrine with overhead cover.

ing the field of fire or other essential qualities. The necessity for making all roofs of deep shelters or other thick overhead cover waterproof is noted.

Drainage is one of the considerations which should be borne in mind by officers whose duty it is to select the site and lay out the work. If possible, a trench should be cut to the lowest point in the surrounding ground such as a ditch, sunken road, or convenient hollow. If such does not exist, soak pits should be dug at convenient intervals, and water pumped or baled out.

Rain-water filters through all soils, especially through loose earth that has been placed over the shelters. Protection is secured by placing on one layer of logs, roofing paper, corrugated iron, tin or zinc, linoleum, canvas, tiles, etc.

It is necessary to provide drainage for water which runs into the shelter through the entrance or seeps through the walls. A pit should be dug near the entrance and the floor of the shelter should be sloped towards it. (1917)

(*d*) The amount of *revetment* necessary for preventing sides of the trenches from caving in depends upon the character of the soil, and the length of time the trenches will be occupied. The use of wire netting and expanded metal for revetting is noted, and also the enormous number of sand-bags required, sometimes running up into the *millions* per mile of front.

Revetments of hurdle, sand-bags, wire netting, and sod are all used, but the first named has been found the most durable. (1916)

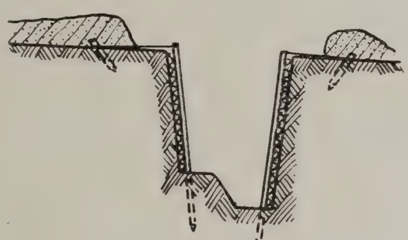


Fig. 49. Wire netting revetment.

The parados was revetted by being covered with gunny sacking held against the earth by upright stakes about 3 feet apart to which was nailed wire netting (chicken coop wire). (1917)

Openings in wire (Fig. 49) $1\frac{1}{4}'' \times 1\frac{5}{8}''$; stakes $2\frac{1}{2}''$ diameter, and 16″ apart. (1916)

Brushwood revetting. Points to note.

(1) Allow 6 inches on both sides of your trench for the revetting, or 1 foot altogether.

(2) Before starting, see that the trench face is flat, and fill in any holes with clay, sods, and small brushwood.

(3) Revetting poles or posts should be about 2 inches in diameter; must be straight and pointed at one end, and sawed off square at the top to avoid splitting when being driven in, and about 1 foot longer than the depth of the trench.

(4) Drive in posts 1 to 2 feet apart, leaving room for brushwood, and arrange so that the post on one side of trench is opposite space between posts on the other.

(5) Brushwood is best about ¾ inch diameter, clear of leaves, and is built up behind the revetting posts until the top of the trench is reached.

(6) Anchor pickets are then driven in, well back, and are staggered to avoid danger of establishing a split in the soil. The tops of the revetting posts are tightly wired to these.

(7) Revetting posts are driven in at all re-entering angles, but only near and at either side of any corner in a trench.

(8) The revetting posts of steps or banquette are anchored to the bottom of posts next above. (P. 68 "Knowledge for War" —Capt. Lake, 1916)

(*e*) *Messing arrangements.* It is believed that unless the occupancy of trenches is to be for very long periods, no kitchens need be provided, as there will be very little cooking done in the trenches aside from the preparation of coffee or tea.

In the trenches before the enemy, tea is much used, often made by the men themselves. The traveling kitchens are brought as near the trenches as possible, often at night, and the food carried in so that the men have at least one full hot meal daily. (1915)

(*f*) *Special arrangements* will be made for emplacement of trench mortars, throwing hand grenades, storerooms for all kinds of supplies, and shelters for officers, as occasion requires. As the emplacement for trench mortars depends on the type of mortar used, and the size and extent of shelters provided depend upon the personnel or material to be sheltered—and differ in no other way from shelter already described, it is not believed necessary to go into details of these special arrangements here. The necessity for storerooms in the trenches is shown from the following:

Depots for material and ammunition. These consist of galleries of variable dimensions, opened in the walls of the trenches and approaches, and usually lined with timber like mine casings. The entrance should be closed with a strong door. They are used to store water, rations, ammunition, grenades, pioneer tools, portable searchlights, field glasses, maps, range finders, periscopes, lighting pistols, rockets, etc. Depots for engineer material are usually installed in the angles of the approaches. Depots for water, rations, tools and sand-bags are usually established about 20 yards to the right of the company commander's shelter. Depots for arms, ammunition, bombs, grenades, and rockets, about 20 yards to the left of the same point. (1917)

X. CONCLUSIONS.

In presenting the following brief summary of general conclusions, the writer realizes that since he has not been able to observe the war in person, and as his time and facilities for studying

reports from the Front have not been as extensive or complete as might have been desired, the subject has really only been outlined in the present article, and that after a more thorough study and investigation, some of these conclusions may be modified in important particulars. However, from information available at present, it is believed that some of the lessons to be drawn from experience in Europe with field fortifications may be stated as follows:

1st: The *general use of field fortifications,* both in attack and defense, and the consequent necessity of a knowledge of the details of their construction by the combat officer; and the lack of a pocket manual on the subject for our service.

2nd: The importance of *protection against artillery fire,* especially against the high-explosive shell of large caliber. This protection is usually obtained by the following means:

(*a*) *Concealment* of all works,—especially from aerial observation.

(*b*) *Dispersion of all works,*—noticeable in the organization of defensive lines in depth, by preparing second and third lines.

(*c*) *Construction* of many *deep* underground shelters, *close* to the firing trenches; of *traverses closer* together and wider; and of *narrower* and *deeper* trenches, each with a *parados* in rear.

3rd: The use of *closed works* prepared for all-around defense in the *second or third* line of a stubbornly contested front, but *not for the first line,* nor *for early stages of contact.*

4th: The necessity of *concealment*—long recognized as important—was emphasized for the following special features:

(*a*) Artillery positions;
(*b*) Machine gun emplacements;
(*c*) Observation stations;
(*d*) Wire entanglements.

5th: The importance of *communication trenches,* and of their great development and extent. The following new features are noted:

(*a*) The lateral "supervision" trench, immediately in rear of the firing trenches;

(*b*) Arrangements for flank fire from "approach" trenches;

(*c*) Arrangements for defense of these trenches when one end has been captured by the enemy.

6th: The enormous use of *wire entanglements,* and consequent perfection in methods of using and building them:

(*a*) Their location *close* to the firing trench;

(*b*) The use of *double or multiple* lines, with the idea of making the entanglement "wide rather than dense";

(*c*) The development of rapid and silent methods of construction, and use of portable types;

(*d*) The construction of many lines perpendicular to the front;

(*e*) The general use of medium height posts and loose and heavy wire.

7th: The *increased use of machine guns,* both on attack and defense, utilizing the element of surprise, coupled with enfilading fire wherever possible; and the general use of open firing positions for these guns.

8th: The necessity for large *supplies* of the following materials:

(*a*) Barbed wire;
(*b*) Sand bags;
(*c*) Lumber and other material for building shelters;
(*d*) Expanded metal and material for building revetments.

9th: The need for *new equipment* in our service, as follows:

(*a*) Periscopes;
(*b*) Steel loophole plates;
(*c*) Flares, rockets, and illuminating bombs;
(*d*) All kinds of grenades;
(*e*) Trench mortars and bomb-throwing machines;
(*f*) Small howitzers for infantry battalions.

In closing, it is desired to state again that the guiding principles of the Art of Fortification have not changed; that is,

1st: Provide for the most effective use of your own personnel and weapons;

2nd: Restrict the effective use of the enemy's personnel and weapons.

Neither has the five elemental means for carrying out these principles changed; that is, *observation, cover, concealment, communication,* and *obstruction.* But it is believed that some change in the *relative importance* of these essentials has been made by recent changes in equipment and weapons, and that certainly the *methods* of securing the objects sought have been modified and perfected in the crucible of three years' world war.

"Tanks"

MILITARY TRACTORS CALLED "TANKS"

A LIST OF REFERENCES GATHERED FROM CURRENT PERIODICAL LITERATURE, PREPARED BY THE LIBRARIAN, IN THE ENGINEER SCHOOL LIBRARY, MAY 28, 1917.

*Item in Engineer School Library, Washington Barracks, D. C.
†Item in Library of Army War College, Washington Barracks, D. C.
°Item in Library of Congress, Washington, D. C.

†*Armored automobiles. A war machine that has undergone many changes. (Scientific American Supplement, N. Y., v. 83, no. 2140, Jan. 6, 1917, p. 4-5. Also in: Army War College Library. Monthly list, Feb., 1917, no. 38)

see illustration [half-tone], p. 4: One of the "Insolent" British tanks, employed at the Somme front.

*Armored car battery for the United States. (Scientific American, N. Y., v. 114, April 22, 1916, p. 429, illus.)

†Armored cars and British tanks in the war. From La Swiss Sportive, Geneva. Oct. 14, 1916. Army War College Library. Monthly list, Jan., 1917, no. 38.

†Armored cars, European war. A German description of the British ''tanks''. From Japan Advertiser, Dec. 25, 1916. Army War College Library. Monthly list. March, 1917, no. 43.

†Armored cars, European war. Picture of the British armored ''tank''. Clipping from The Sun, N. Y., Oct. 17, 1916. Army War College Library. Monthly list, Dec., 1916, no. 46.

†Armored cars, European war. Picture of a British ''tank'' car in action. From N. Y. Times, Dec. 17, 1916. Army War College Library. Monthly list. Feb., 1917. no. 37.

*Armored caterpillar tractor. Army and Navy Journal, N. Y. Sept. 23, 1916. 750 words. See also International Military Digest, N. Y. Annual, 1916, p. 74.

†*Armored tractors in the European war. (Scientific American, N. Y. v. 115, Oct. 7, 1916, p. 322-323. 2000 words. Illus.) Army War College. Monthly list, Nov., 1916, no. 39. See also International Military Digest, N. Y. Annual, 1916, p. 74.

†°The automatic land cruiser. Part played by American company in developing the ''tanks'' of French battlefields. (Iron Age, N. Y., Sept. 28, 1916, p. 695, illus. Army War College. Monthly list, Nov., 1916, no. 38)

*Automobili corazzati e armati da battaglia i ''Tanks'' inglesi. Rivista di Artiglieria e Genio, Roma. xxxiv (54a) annata, v. 1. Gennaio, Febbraio e Marzo, 1917, p. 98-103. 1940 words. 1 half-tone (2 fig.).

*Baby tractor of great power. (Scientific American, N. Y., v. 116, March 31, 1917, p. 323, illus.)

°Britain's super-dreadnoughts of the land. (Literary Digest, N. Y., v. 53, Sept. 30, 1916, p. 815-817. Illus., map.)

†British armored ''tank'' cars. (Current History, N. Y. Times, N. Y. Nov., 1916, p. 242. Illus. Army War College Library. Monthly list, Dec., 1916, no. 47)

*Caterpillar tractor becomes a tank. (Engineering and Contracting, Chicago. v. 46, Oct. 4, 1916, p. 289-290)

°Conquering heavy roads in France. (Literary Digest, N. Y., v. 53, Oct. 7, 1916, p. 891. Illus.)

†°Description of the British ''tanks'', an adaptation of the caterpillar tractor. (World's Work, N. Y., Dec., 1916, p. 195. Army War College Library. Monthly list, Jan., 1917, no. 39)

°Double-steer artillery tractor on Ford chassis. (Automobile, N. Y., v. 36, April 5, 1917, p. 694. Illus.)

†*The evolution of the tanks. (Engineering, London. Oct. 20, 1916, p. 386. Army War College Library. Monthly list, Dec., 1916, no. 45)

* . . . ''An experimental tank will be built.'' See Military Committee Hearings. (Army and Navy Journal, N. Y., Jan. 6, 1917. 400 words) See also: International Military Digest, N. Y. v. 3, no. 2, Feb., 1917, p. 70.

°Four-wheel drive for heavy tractors. W. F. Bradley (Automobile, N. Y. v. 35, Aug. 24, 1916, p. 311-316. Illus.)

*Gepanzerte wagen als kriegsmittel. (Armored cars for military purposes) in: Schweizerische zeitschrift für artillerie-und geniewesen, Frauenfeld. v. 53, no. 3, März, 1917, p. 74-81; no. 4, April, 1917, p. 110-114.

°Gigantic battle-machine. (Literary Digest, N. Y. v. 53, Dec. 9, 1916, p. 1533. Illus.)

°Great land ironclads and victory. H. G. Wells. (Current History, N. Y. Times, N. Y. v. 5, Feb., 1917, p. 892-896. Illus.)

°Imagination in war. (Living Age, Boston. v. 291, Oct. 28, 1916, p. 236-239.

°Inside a tank. (Literary Digest, N. Y. v. 53, Nov. 18, 1916, p. 1361)

*Internationalizing the armored land-ship or tank. (Scientific American, N. Y. v. 116, April 7, 1917, p. 116. Illus.)

†*Land cruisers in the battle of the Somme. (Scientific American, N. Y. v. 115, Oct. 28, 1916, p. 391. Illus. Army War College Library. Monthly list, Dec., 1916, no. 44. See also International Military Digest, N. Y. Annual, 1916, p. 75.)

°New British motor monsters in action. (Current Opinion, N. Y. v. 61, Nov., 1916, p. 362)

†Photos of tanks in action. (Illustrated War News, Nov. 29, 1916, p. 19. Army War College. Monthly list, Jan., 1917, no. 40)

°Steel-shelled armadillos of the Somme. (Independent, N. Y. v. 88, Oct. 30, 1916, p. 192-193. Illus.)

*A tank in trouble. (Scientific American, N. Y. v. 116, Jan. 13, 1917, p. 59. 400 words. Illus.) See also International Military Digest, N. Y. v. 3, no. 3, March, 1917, p. 122.

The tanks. Editorial. (Army and Navy Gazette, London. Sept. 23, 1916. 375 words) See also * International Military Digest, N. Y. v. 3, no. 2, Feb., 1917, p. 70.

°Tanks and the hose of death. R. T. Townsend. (World's Work, N. Y. v. 33, Dec., 1916, p. 195-197. Illus.)

°Tanks, tractors and other pre-historic monsters of to-day. (Current Opinion, N. Y. v. 61, Nov., 1916, p. 350-351)

°Those tanks. (Literary Digest, N. Y. v. 53, Nov. 4, 1916, p. 1166)

°Two new types of tanks: photos. (Automobile, N. Y. v. 36, p. 641. March 29, 1917)

°H. G. Wells takes a ride in a tank. (Current Opinion, N. Y. v. 62, Feb., 1917, p. 148-149)

†*Walking, Hopping, Creeping and Crawling mechanical beasts. Various traction mechanisms that might be employed for armored battlecars in view of the use in European war by British on the French front, Sept., 1916. (Scientific American, N. Y. v. 115, Sept. 30, 1916, p. 305. Illus. Army War College Library. Monthly list. Nov., 1916, no. 37.)

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MAJ. GEN. GEORGE L. GILLESPIE

1841-1913

George L. Gillespie.

BY

Col. W. R. Livermore,
U. S. Army.

George Lewis Gillespie, son of George Lewis and Margaret Ewen Gillespie, was born in Kingston, Tenn., on the 7th of October, 1841. In May, 1858, when his father was living at a short distance from Chattanooga, and he was attending the Western Military Institute at Nashville, he was appointed to the U. S. Military Academy at West Point.

Throughout his course there, his class standing was either first or second. He was a model of military excellence of which the Corps of Cadets was justly proud. Many of his classmates were from the South; and the tone of the class was eminently Southern. Gillespie remained loyal to the Union. The class, which numbered 62 in 1861, was reduced in 1862 to 28. In July, 1862, Gillespie was graduated second in his class and assigned to the Corps of Engineers as Second Lieutenant. As there was then a temporary suspension of hostilities, and no call for the young officers at the front, he was assigned to duty at West Point as Instructor in Artillery and in command of Company C.

In September he served for a short time on the staff of General Burnside, and then took command of two companies of Engineer Battalion attached to the Army of the Potomac. Throughout the campaigns of 1862 and 1863, Gillespie was engaged in action or in reconnoitering, bridge building, or fortifying. In these campaigns the bridges near Fredericksburg on which the army crossed and recrossed were built under heavy and destructive fire. In the Gettysburg campaign, he remained with the battalion, which bridged the Potomac at Edwards Ferry and moved on to Westminster, which formed Meade's base of operations and where his trains and stores were assembled. Gillespie was in command, and had charge of its defenses; an

important post for so young an officer, especially as Stuart's Confederate cavalry was then hovering around the Federal flank and rear in hopes of destroying these trains and supplies.

In the winter of 1863-1864 he was stationed in New York and Philadelphia, recruiting for the Engineer Battalion. In May, 1864, Gillespie, then a Captain, rejoined the army at North Anna. On the 26th he was sent with Warren's Corps near the left of the Federal line, under orders from Meade to watch operations there and report from time to time. Meade wanted to be notified of the exact time when his first guns were heard. This was at 3 p. m., and it was soon followed by several shots in rapid succession.

He soon became convinced that Sheridan was fighting at Cold Harbor. It was growing dark, and the timber which he entered was very dense and the undergrowth very thick; beguiling the enemy's pickets and galloping through a rattling fire of musketry, by about 7 o'clock he overtook Sheridan's Cavalry, fighting with the enemy in front of Cold Harbor, which soon came into their possession. He then had to return and report to Meade, whom he reached by midnight.

On the following day Gillespie and Benyaurd were put in charge of the defenses of Cold Harbor; Gillespie had the left. After Grant's bloody assault, on the 3rd of June, the work of sapping and mining began in earnest. In about ten days, when Grant fully realized his failure at that point, he moved his army by the left flank. On the night of the 17th, the Engineer Battalion threw a bridge more than 2,000 feet long across the James, on which the army crossed.

At the siege of Petersburg, Gillespie was employed in building earthworks, in sapping, mining, reconnoitering, and all kinds of engineering work, until the end of October, 1864. He was then relieved from duty at Petersburg and placed on Sheridan's staff, and was soon made Chief Engineer of the Army of the Shenandoah. He became strongly attached to Sheridan, whom he followed throughout the campaign. Before the Battle of Five Forks, by Sheridan's direction, he selected the ground for Warren's Corps to occupy when, by Grant's orders, it was for the time placed under Sheridan's command, and then kept with him until the final surrender at Appomattox.

Throughout his service in the field, Gillespie performed all the work that fell to his lot with eminent ability and to the hearty approval of Generals Grant, Meade, Sheridan, Warren,

and other general officers, as well as those of his own corps with whom he served. His topographical instinct and training helped him to find his way over the battlefield, and over the unmapped and unexplored theater of operations; to take advantage of the terrain for attack or for defense; to direct the movements of his own troops; and to define the positions and plans of the enemy.

For gallant and meritorious services during campaign before Richmond, and in the campaign from Winchester to Appomattox Court House, he received respectively the brevet of Major and of Lieutenant Colonel; and for most distinguished gallantry in action near Bethesda Church, when he went through the enemy's line to communicate with Sheridan at Cold Harbor, he received from Congress a medal of honor.

In 1865, when the war was over, Sheridan and his staff were sent to New Orleans to receive the surrender of Kirby Smith, then in Arkansas, and to pacify the Southwestern States. Maximilian and the French troops were then occupying Mexico. Gillespie was sent to Brownsville to watch operations, and to represent the United States in international conferences with the prominent Mexican leaders. In 1867, he was ordered to Portsmouth, N. H.

In 1871, he was promoted to Major; in 1886, to Lieutenant Colonel; in 1895, to Colonel of Engineers.

From 1867 to 1901 he was stationed at Portsmouth, N. H.; at Chicago; in Oregon; at New York, and at Boston, in charge of the construction of permanent fortifications, of light-houses, of surveys, and of river and harbor work. A most interesting work was in the construction of a first-class light-house and fog signal on Tillamook Rock in the Pacific Ocean, lying about a mile off the coast of Oregon and 20 miles south of the entrance to Columbia River. It is a bold basaltic rock, about 200 feet wide and 120 feet high. Exposed to the full force of the ocean waves, it was extremely difficult to approach it even in calm weather, and this made the construction of a light-house on this rock a masterpiece of engineering. Gillespie prepared several new devices for landing men and material. A cable was stretched from the mast of a vessel, moored about 300 feet from the rock, to a projecting ledge 85 feet above the sea level, and rigged with a large single block, called the "traveller," which moved freely along it and carried a large projecting hook underneath; the men and supplies were transferred by a very novel arrangement, called the "breeches buoy."

In 1882 the increasing commerce of New York demanded deeper water in the outer harbor; and this it had been found impracticable to obtain by dikes alone. In 1884, after a careful examination, Gillespie recommended that the channel should be excavated to the required depth, in the belief that this depth could be maintained more economically by dredging than by the scouring action of the current. Gillespie had charge of this work in its early stages, and he and his successors have dug one channel after another by hired labor with large dredges, designed and built for the Government, until they have made New York Harbor one of the finest in the world.

In May, 1891, he became Brigadier General and Chief of Engineers, U. S. Army, and a member of the Board of Ordnance and Fortification, of which in August, 1903, he became president.

In 1894, he was appointed by President Cleveland to represent the War Department at the Sixth Congress of International Navigation at the Hague.

When the Spanish War broke out in May, 1898, he was made Brigadier General of Volunteers, and from the 30th of June to the 4th of October he commanded the Department of the East, with his station at Governors Island.

An account of the civil work for which as Chief of Engineers he was responsible is, of course, beyond the scope of this memoir. The incessant labor which the care of these works involved did not prevent him from giving his most earnest attention to all the details of the construction and operation of the seacoast fortifications, which, while he was in office, were more than half completed. When these works had first been planned, their action was only directed against the water, and it was thought that our volunteer armies could defend them on the side of the land. Gillespie, however, had plans prepared by the Board of Engineers for temporary fortifications surrounding the seacoast batteries on the land side, to be constructed at short notice in time of war.

Just before he came into office, the force of engineer troops had been increased from one battalion to three. Soon after, when the torpedo service was turned over to the artillery, the Post of Willets Point was turned over with it, and the Engineer troops were moved to Washington and elsewhere. Under Gillespie's direction, elegant and commodious buildings were erected at Washington; and especially fitted up to give the troops practice in their military duties, as well as in the trade of car-

penter, blacksmith, mason, plumber, printer, and photographer; in the management of steam machinery, and in mechanical and topographical drawing. He had experiments conducted to improve the ponton service, and had equipment prepared to facilitate the debarkation from a fleet to an open coast. He reorganized the Engineer School, provided a manual for training enlisted men in all the duties of Engineer troops, and developed the details of their equipment.

In order to bring about a closer cooperation of the several branches of the service charged with the defense of the seacoast, upon Gillespie's recommendation, an officer of the Artillery, one of the Ordnance, and one of the Navy, were added to his Advisory Board on Fortification. Gillespie realized that perfection in all the details of drill and of routine administration were not all that was required to operate an army or even a fraction of an army in time of war. He was among the first to advocate the establishment of a General Staff, and of a War College similar in its general plan to that of the Navy, which had proved to be so satisfactory. He was especially gratified in November, 1901, to be detailed upon the War College Board, and took a deep interest in its organization as well as in that of the General Staff. He retired from active service June 15, 1905. He died at Saratoga, on the 27th of September, 1911, and was buried with military honors at West Point on the 29th.

It was not merely as an able and accomplished soldier and a skillful engineer that General Gillespie will be remembered. He was deeply religious; tender and devoted to his family; neither shirking responsibility in his official duties nor tolerating improper interference with his work; mindful of social observances; refined and courteous in his dealings with all men; cheerful in his manner; and magnetic in his personality. The foundation of his character, around which all these traits appeared to cluster, was his unswerving fidelity.

Extracts from "Des Travaux du Fleuve du Rhin."

BY

A. J. CH. DEFONTAINE.

[Translated by Col. C. McD. TOWNSEND, Corps of Engineers, U. S. Army.]

INTRODUCTION.

In this book, which was apparently written about 1838, as a text-book for the *Ecole des Ponts et Chaussées,* are described the efforts of the French to improve the Rhine along the Alsatian frontier. The causes of the failures of some of the works are explained, and as there is at present a tendency to rediscover methods abandoned on the Rhine a hundred years ago, and urge their employment on our Western rivers, the following extracts from the report are considered of sufficient interest to District Engineer Officers to merit translation.

The "*tunnage ordinaire,*" shown in Plate XLIX, is an illustration, with much greater elaboration than is usually proposed for the Upper Missouri, of the various methods of bank protection which rely on anchoring fascines and limbs of trees at the water surface.

The "*epi de bordage*" in Plate XLIX has been reproduced in the fascine work employed by the farmers on the Lower Missouri. The Neale Dike, with its cells filled with deposits, is but a weak reproduction of the gabions and wicker work, filled with gravel, used by the French. Finally, the great advantages that certain inventors claim for dikes inclined either up or down stream (Sewall dikes of the Red River, and railroad dikes on the Kansas and Missouri rivers) are fully analyzed in the report.

CHAPTER II. THE WORKS OF THE RHINE.

33. *Special Object of these Works.* We have said that the works of the Rhine have for their special object to direct the principal current of the river in the least destructive manner possible for the banks, on which are generally located the great levees intended to

limit floods. The works of protection which we are about to describe rarely are beneficial to navigation. Often even these works cause danger to descending navigation and burden that ascending either from the wing dams which are created, or by the greater velocity to be overcome when, through the closure of secondary chutes, boats are forced to take the principal and always rapid branch of the river.

34. *The Works Are All for the Advantage of the Locality.* It is necessary, then, to recognize that these works have almost for their exclusive purpose the protection of the property which borders the river.

Note 11. This property abandoned to itself would certainly be unable to make the sacrifices necessary for its preservation, if the State did not come powerfully to its aid, but it should so much the more assist in these works as the isles and artificial deposits become the property of the riparian owners.

Very often, however, the communities and riparian owners speculate on the value of the wood for fascines which it is necessary to cut on their lands in order to preserve them from inevitable submersion.

Many riparian proprietors have gone so far as to claim indemnity for lands which it was not believed should be protected at the expense of the State.

To attain this object and independent of the limits to inundation which the levees create, care is taken to give to these works the direction best adapted to each locality. Sometimes the course of the river is straightened by cut-offs, then false arms are closed by closing dams, in the effort to prevent flow on neighboring territory. These closing dams are located so as to induce the filling up of the chute which they close. Their ends are extended for a sufficient distance over the low lands, and cross connected. They are maintained submersible at mean stages, and determine the filling of the sand bars and low lands. The banks are then protected either by mixed riprap, or wing dams, according to the different local conditions.

35. *Division of the Works as to Temporary and Permanent.* The works of the Rhine are divided into temporary and permanent works.

36. *Temporary Works.* Temporary works are intended to close chutes, either principal or secondary, by forming deposits, and they become obliterated in the deposits which they create. They are made of fascines; as the object is to act with great masses to produce instantaneous effects whose results become independent of the works which have created them. It is not necessary, wherever once the results are obtained, that the material employed have a long life. Therefore the employment of fascine work is economical and practical. In many instances also the necessary material is found in the vicinity. It is possible besides, either by planting

willows or by maintenance, to prolong the existence of this kind of work when the effect intended does not occur as promptly as expected.

37. *Permanent Works.* Permanent works comprise levees and most of the works which are constructed for the protection of the banks.

The levees, to be durable, have need especially of a good foundation. It is, moreover, necessary that they be given suitable proportions and constructed of material which will render them the least permeable possible. It is also necessary in order to prevent submersion that their height be determined with reference to great floods, which is not always easy on account of variations in the course of the river and of the form and extent of its new section.

A certain levee, which is now found more than one and a half meters above the great floods, did not exceed by one-half meter the highest water at the time of its construction; some land which had never been submerged, when it was distant from the principal course of the river, to-day is in very great need of protection by a levee because it will be submerged at each flood to a depth of more than 1 meter.

38. *Works of Protection Must Be Durable.* Works intended for the protection of banks, especially when they are regarded as definitely located, must present the quality of durability, to a certain extent unlimited.

Banks are protected either by revetments or by wing dams which tend to remove the effects of the currents from the roots of these works.

As revetment works do not cause a sanding of their contours, it is necessary that the surface of their slopes be covered with material more durable than fascine works. The same applies to the extremities of wing dams, which, exposed constantly to the action of the river, have only an ephemeral existence, if they are not protected by some kind of indestructible substance. It therefore results that for revetment work and wing dams there are employed fascine work and a small volume of large stone.

39. *New Application of Fascine Works.* Under this heading we will insist on the new application of fascine work which has enabled us to prepare in advance and without great expense the elements of a mass notable for the simplest construction, by employing for all structures only the osiers which grow on the sand bars, and the gravel of the Rhine. We are thus prepared to introduce an economy

Pl. XLVII.

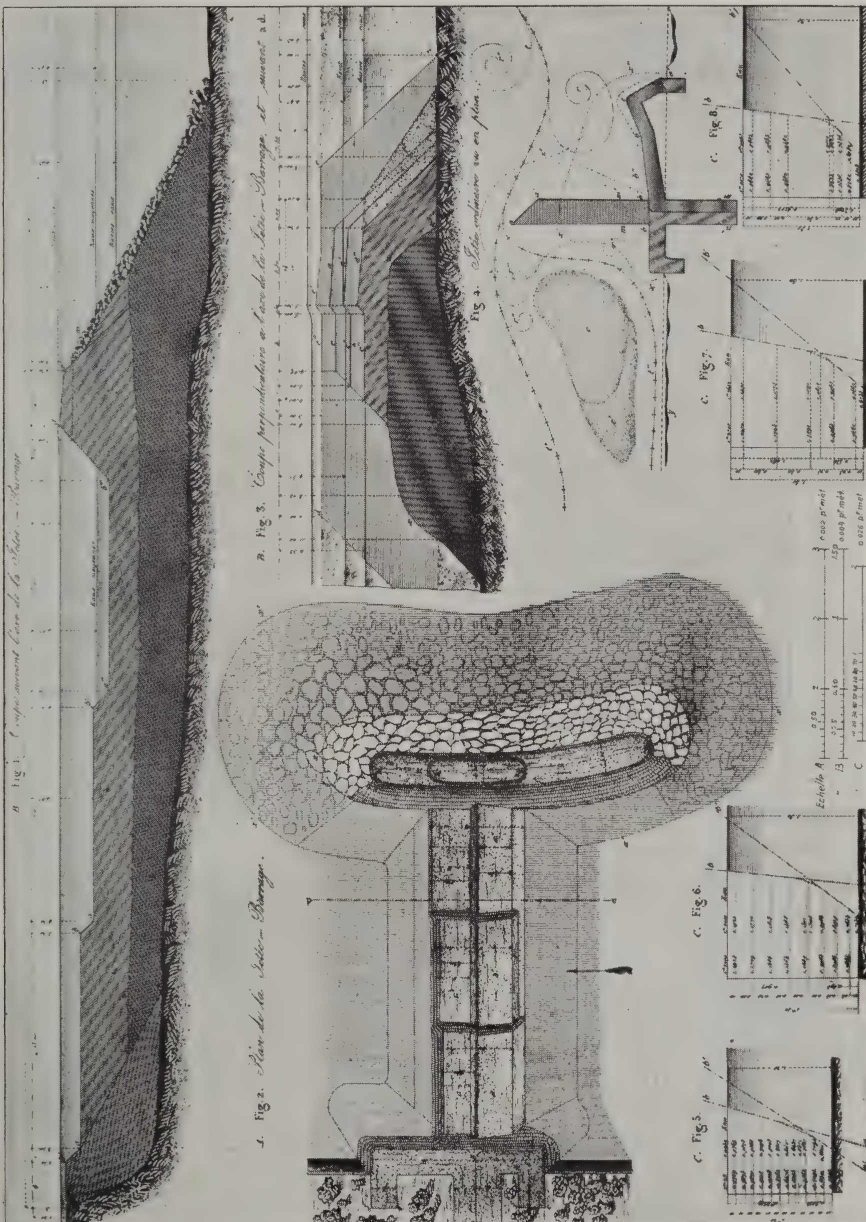


Fig. 1. Coupe suivant l'axe de la Jetée. — Barrage
Fig. 2. Plan de la Jetée — Barrage.
Fig. 3. Coupe perpendiculaire à l'axe de la Jetée — Barrage, et suivant a d.
Fig. 4. Jetée ordinaire vue en plan.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Echelle A

very remarkable in this class of work and above all there has been rendered possible in the most difficult cases the execution of works of this class of dimensions and importance to a certain extent colossal, such, for example, as the complete closure of the course of a river, so as to give it another direction whatever be the volume of its waters, the velocity of its current, the depth of its section, and the mobility of the material composing its bed.

CHAPTER V. CLOSING DAMS.

98. *The Closure of Chutes and Principal Arms.* The chutes which furrow the bed of the Rhine cause very frequently variations in the course of the thalweg, and are, as has been said, one of the principal causes of the discharge of the river on adjacent territory during floods. For this reason those chutes are closed which would lead the river in directions destructive to the French bank.

Also, in concert with the Duchy of Baden, in an attempt to regulate the portion of the Rhine comprised between Kehl and Strassbourg, the entire course of the river has been changed by the new processes in order to give it a new direction.

A belief that the construction of these closing dams merits the attention of scientists, has determined us to give the following details.

99. Closing dams are always submersible, at least in part. In closing any chute, on the one hand, everything has been done for the protection of the banks, and if by certain arrangements these dams caused the sanding-up of the chute closed, everything has been obtained, on the other hand, for the increase and preservation of the riparian property. In order to fulfill these conditions, all the closing dams which we have constructed on the Rhine have been submersible, either completely or in part.

100. The closing dam must be distant from the upper entrance. Every time it is a question of closing a chute of the Rhine, and contrary to what has been practiced on most other rivers, we have always placed the closing dam at a certain distance from the upper entrance without bringing it too close to the lower. Also, our closing dams have never been located at the opening itself, because this last arrangement, in creating in a certain way by the dam itself the bank of the new bed, has always appeared to us to expose this work to a prompt destruction and, indeed, if the dam is not submersible, unless one protects the banks to a sufficiently great extent, it will soon be turned by caving, and, if it is submersible, the

danger, though it may be less apparent, is none the less real.

It is known, besides, that the best means of protection to oppose to the attack of a current is to cover the point threatened with a certain amount of dead water, against which the action of the current becomes exhausted. Now in placing the dams distant from the entrances, there is obtained without trouble this assistance. There is no necessity to occupy oneself with their protection from the effects of the current of the superior arm from which they have been isolated. There is, moreover, more security and freedom in the execution of all the maneuvers of the equipment employed in the construction of the work, so that the chances of accidents are considerably diminished without preventing, however, that from time to time the loss of some workmen has to be deplored.

As has just been said, the object proposed by the closure of a chute, is not only to arrest the enlargement of the chute which it tends to make at the expense of the bank, but also to cause the most promptly possible its sanding-up. Now for this purpose it is necessary that the dam be placed below the upper entrance and that at the same time it be submersible when floods attain a certain height. If it were otherwise, the waters charged with the material they transport, having once filled the closed arm and made their deposit, would find no point of issue where they could flow off and make room for other waters equally charged with material in suspension. The deposit would then be only inappreciable, while it would be considerable if at the time the first waters had dropped the material in suspension they can be replaced by other laden waters, and this process continued during the duration of the flood. This can only take place by means of dams, submersible or with passes.

If the dam is placed near the outlet of the chute, and in this portion of the work is submersible, in order to give it a marked influence on the velocity of the current above, and to facilitate the formation of deposits, it is necessary that it almost always have a great height, especially for secondary arms, whose slope is greater than that of the main river; almost always this height will exceed that of the neighboring banks. It will cause, then, in the ordinary state of the river, the submersion of riparian property, and also cause considerable damage to neighboring crops. Besides the retention of the water becoming greater than it would have been if the dam had been placed further upstream, the difficulties of construction also become greater and the cost proportionately excessive.

If, on the other hand, in this position the dam has the ordinary height; that is to say, about a half meter below the bank, its influence is exerted upstream only to a slight extent and, besides, the velocity remaining almost the same, no deposit will be formed. It would be better, then, to move the work upstream, so that its influence will be carried to the entrance.

The distance to preserve between the dam and the upper entrance has then a limit which, if exceeded, creates great difficulties without obtaining any definite advantage.

101. A single closing dam is not sufficient for the complete filling up of a chute.

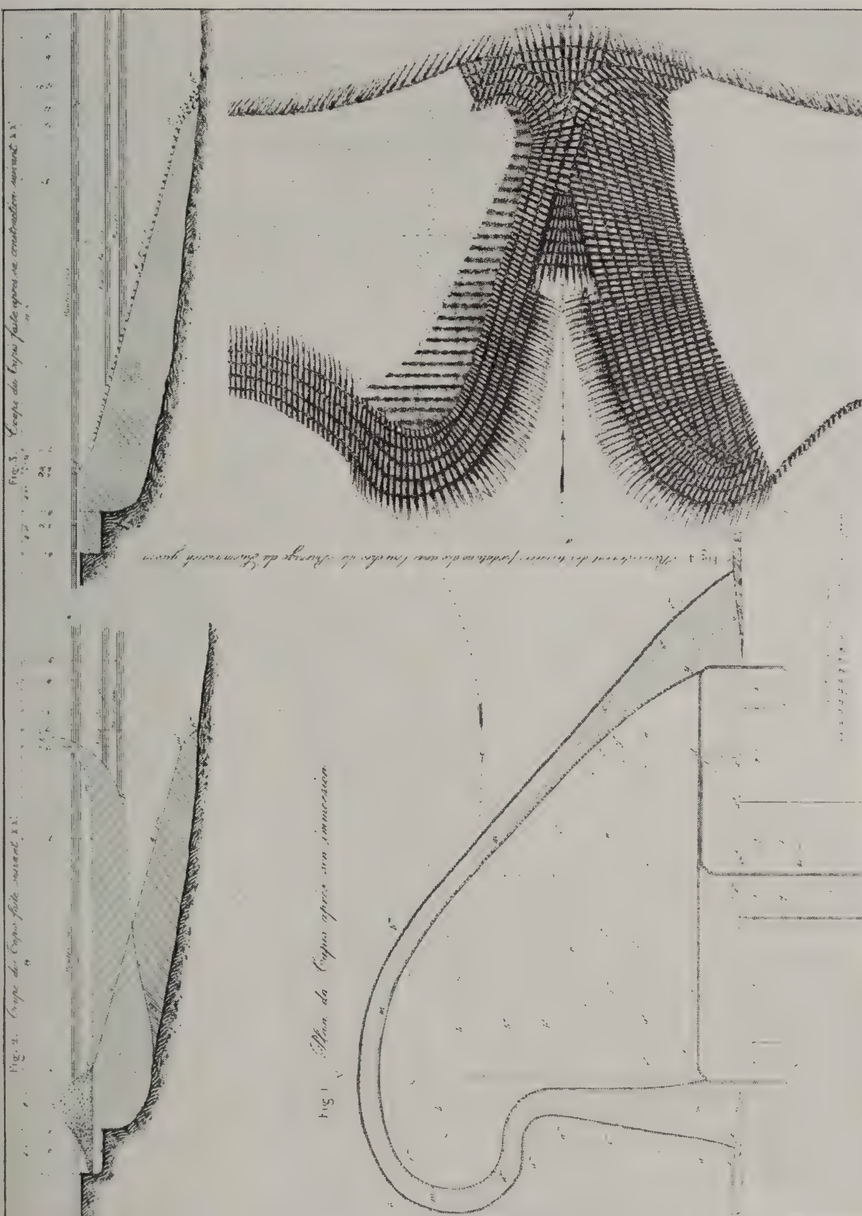
It should, besides, be observed that by means of a single closing dam, whatever location may be given it, only rarely can the complete filling up of a chute be accomplished when of considerable extent. Indeed, from the time that the velocity is appreciably diminished by the construction of the dam, the gravel transported no longer enters the closed chute. It is deposited only at the upper entrance and follows the new bed. The deposits in the closed chute are then formed only from the sediment suspended in the waters of floods. These deposits can only be obtained by dividing the length of the chute into many basins, created by sills or secondary closing dams less elevated than the main one.

Below the last secondary dam the sanding-up is only by reason of the eddy of the confluent, which begins to be developed at the mouth of the closed chute.

102. *Closing Dams Have Been Placed Perpendicular to the Banks.* All the dams which have been constructed have been located perpendicular to the banks, in order that they may have less length and the fall over them be the least destructive to the banks. With an oblique direction, the flow acts normal to the crest of the dam and is carried toward that of the two downstream banks which forms the smallest angle with the direction of the dam. It is necessary then to protect this bank, while it is not attacked when the dam is perpendicular to the current.

The oblique direction presents, also, a difficulty in the construction of the fascine work in that portion of the structure placed on the bank which forms the greatest angle downstream with the direction of the dam. In proceeding upstream with the layers of fascine work which must compose this part of the structure, greater resistance is experienced and there is more danger. Besides, in this situation the shock of the current is received, de-

Pl. XLVIII.



livered obliquely from the portion of the dam which starts from the opposite bank. Indeed, for wattled dams, the location oblique to the current is inadvisable, since the placing of the wicker work, already so difficult when the axis is in the direction of the current, would become impossible if the axis made an angle with it, and indeed the wicker work would all by the location be driven against the piles, none would go to the bottom.

It could, in truth, be objected that by means of the oblique disposition it is proposed sometimes to give less height to the water when in flood above the crest of the works, and diminish the caving below in the bed of the stream, but particularly on the Rhine, in order to give more solidity to the structure, closing dams are placed in the portion of the river already deeply scoured, and the aprons are given a sufficient thickness so that nothing is to be feared from the fall produced by the reservoir above.

In every case, indeed, the establishment of a surplus layer of fascine work on the apron and the prolongation of the surface for some meters more, in the direction perpendicular to the banks, will be a less expensive operation than the structures rendered necessary by the great volume of work following the greater development in an oblique direction. Thus the economic question should be decided definitely in favor of a direction normal to the river.

103. *Downstream Aprons and Abutments.* In all submersible closing dams or those with submersible passes, it is necessary to have an apron whose extent is proportioned to the height of the fall, in order to remove from the principal mass of the dam the effects of scour. Due to this precaution, the dams once finished have never experienced damage from deepening of the bed of the river below the works during floods, deepenings which on the Rhine attain, nevertheless, their maximum depth very promptly. It is necessary also to attribute this good result to the mobility and flexibility of the material employed in the construction of the work.

The dams have always been in danger at their abutments. We have, however, constantly succeeded in preserving the ends of the structure by a very simple means, which consists in protecting the surface of the submersible ground with what is called Layers Prolonged. (112)

104. *General Disposition of the Closing Dams.* The dams and sills intended to close the chutes of the Rhine are constructed by different means, according to the depth, the slope, the velocity, and volume of water of the chute to be dammed.

We do not mention the mobility of the bed, which is almost everywhere the same, and, all other things being equal, there will be in employing the same method almost everywhere the same scour. It is this great mobility of the bed that creates all the difficulties in constructing closing dams. If the bottom of the river bed were solid, by employing simply the system of ordinary fascine work and following in their construction the details to which we will return, the closure could be made without trouble of any arm, however important it may be, but other precautions are necessary in view of scouring which can excavate to a depth of 15 meters below low water.

All the closing dams built on the Rhine, for reasons which we have explained (100) have been located from 200 to 250 meters from the upper entrance.

105. *Length of Submersible Passes; Level of Their Crests.* When these dams have a length greater than 30 meters they have been composed of two parts insubmersible, of a length dependent on the width of the chute to be closed, and a submersible portion whose length, as well as its elevation, varies with the width of the chute and the velocity which it is desired to preserve upstream. The length of these submersible portions has always been limited between 30 and 60 meters.

As to the height of the crests of these passes, it is often necessary to subordinate it provisionally to the stage of the water at the time of the closure of the dam. In general, when one is not too much burdened by the height of the water at the time of complete closure, the crest of the passes is placed at from 1.50 meters to 2.00 meters below the greatest floods.

106. *Aprons to Receive the Fall.* In order to prevent the scouring which results from the fall of the water passing over the submersible portion of the principal mass of the dam, there is placed downstream an apron whose width depends on the height to be overcome. This width has been fixed at 10 meters for all falls less than 1.50 meters. For those which are greater, this width is increased by five times the difference between the real height of the fall and the initial height of 1.50 meters.

The apron, by its vertical thickness, must present the greatest solidity. For this reason care is taken to establish the submersible pass in the location of the greatest depth, and when this is not 3 or 4 meters the necessary scour is permitted to attain this thickness.

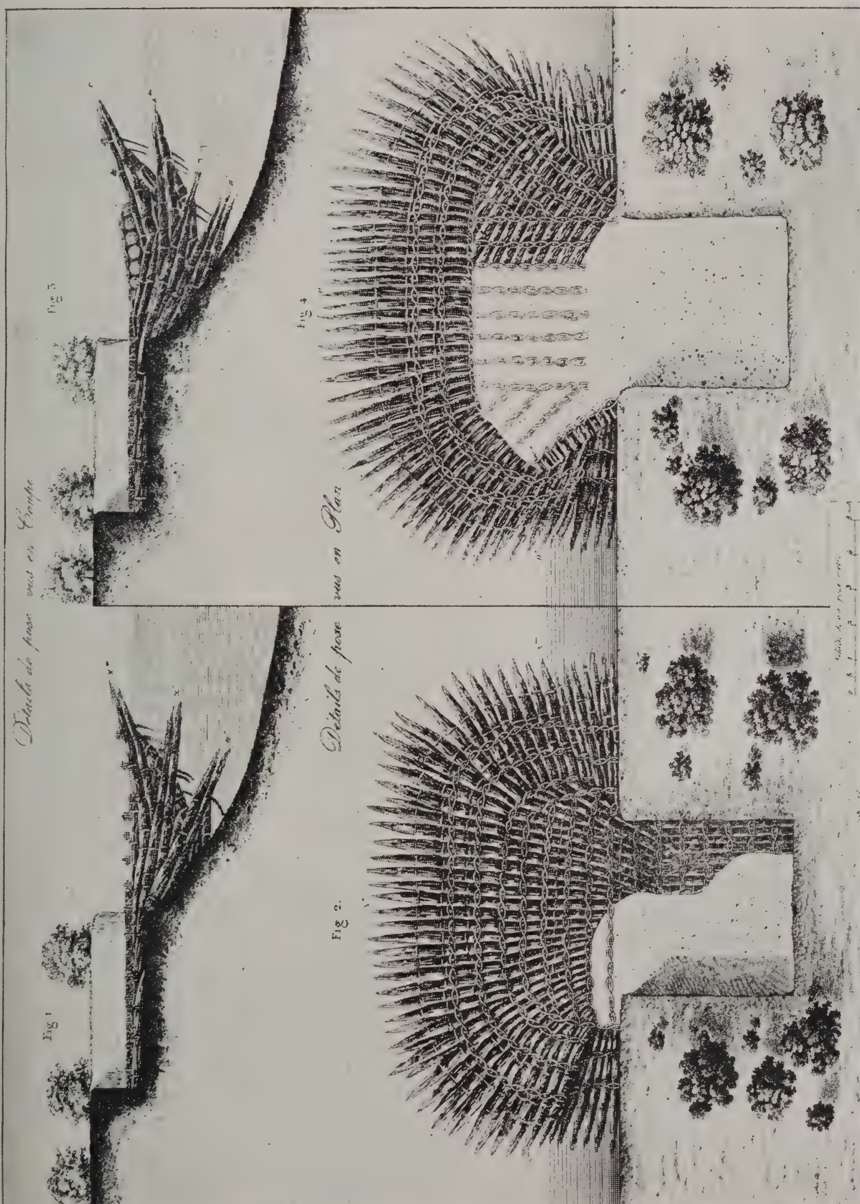
The apron is held at the level of the banquette, which ordinarily exists below the dam and by means of which the irregularities are

made to disappear, which, in the placing of fascine work, result from the difficulties encountered in construction. These difficulties, which it is necessary to combat at all times, depend upon a number of circumstances, such as the variation of the level of the water, the action of the currents, the partial submersion which this action determines, etc. One can then align their crests and regulate their profiles. All the irregularity of the foundation renders therefore necessary only giving a banquette a width which varies between 3 and 4 meters.

107. *Abutments Corresponding to the Insubmersible Parts of the Closing Dam.* The junction of the dam with the slope of the banks is covered and protected by means of a mass of fascines, which are called abutments and which are developed up and down stream from the insubmersible parts. The upper surfaces of these abutments are made flush with the natural surface of the banks, with which they correspond and in which they are rooted at their ends. The upstream abutments have a length of 10 meters and those downstream 20 meters. They are given a width of 4½ meters at the crown.

108. *Dikes Above the Passes to Protect the Slopes.* Above the passes of the large closing dams there are constructed masses in the form of dikes which extend in their length to several meters beyond the foot of the upper slope of the insubmersible parts. These masses have for their object to prevent the establishment, at the time of floods, laterally to the dam, of currents which, directed on the submersible pass, would necessarily drag away the gravel-fill which comprises the slope of these works. These dikes are constructed to the same height as the downstream crests of the insubmersible parts. They are given a thickness of 6 meters at the crown.

109. *Slope of the Works.* The slope of ordinary fascine work for closing dams is limited, as much as possible, to 45°. Sometimes, for the large dams when the depth becomes considerable, it is necessary to give still less inclination, in order that the partial layers, by means of which we approach the point of junction in the closure, be not too extended. Nevertheless, the slopes of the aprons of the passes have 2 meters of base to 1 of height. As to the slope of the deposit of gravel placed above the dam and intended to prevent filtration, they are regulated for great depths to 2 of base to 1 of height. When these depths do not exceed 4 meters, they are given as much as 3 or 4 meters of base to 1 of height, so that they will have sufficient thickness to prevent filtration.


Détails de pose vus en Coupe
Fig 3
Fig 1
Détails de pose vus en Plan
Fig 4
Fig 2.

Pl. XLIX.

110. *Junction of the Submersible and Insubmersible Parts of the Closure Dam with Levees.* The dams with submersible parts are always joined at one of their ends to the great levees by means of a branch of levee of more or less length, which is brought to some meters from the bank of the closed chute. Without this precaution the water of the river when in flood, being diverted onto the natural soil, would not delay in scouring a passage and making a new bed.

[Description of details of construction work omitted.]

111. *Small Closing Dams Which Are Entirely Submersible.* When the chute to be closed has a width of less than 30 meters, the dams are entirely submersible, and the arrangement of the pass and apron is to a certain extent always the same. This pass is kept ordinarily 0.50 meter below the banks; the downstream abutment is in construction similar to those of insubmersible dams. They are given a length of 15 to 20 meters, according to the length of the apron, which they exceed by 6 to 7 meters, but the upper abutments are constructed in a peculiar manner.

112. *Layers Prolonged and Their Object.* As the dam is submersible and as it often occurs that the waters can also cover a great extent of neighboring territory, in order to attain the double object of permitting the floods a suitable outlet and inducing deposits on the low land, there is built on the ground a kind of dam of slight elevation called Layers Prolonged. They start from the upstream abutments and extend perpendicularly to the closed chute until more elevated land is encountered, so as to make a junction with a branch of the levee.

[Description of construction omitted.]

The layers prolonged have their crests generally 0.50 meter below the great floods.

115. *Different Methods of Construction Applicable to Closing Dams.* Closing dams are made of ordinary fascine work when the chute to be closed is dry or can be made so by the construction of cofferdams at their entrances. They are also made of riprap and wicker work and finally of riprap and ordinary fascine work.

[Descriptions omitted.]

CHAPTER VII. PROTECTION OF BANKS.

231. *Weak Resistance of Banks.* We have many times repeated that the banks of the Rhine were formed of alluvium of very little

consistency and that if they were not protected they would be promptly destroyed by the erosive action which the great currents of the river tend to exercise on the banks and bed.

232. *Fascine Work.* For a long time the banks attacked by the Rhine were protected only by simple works or ordinary fascines, called "*Epi de Bordage*" (Fig. 5, Plate LXVI).

These works were established a little in front of the banks and parallel to them. They were no more elevated than the natural terrain, to which at about every 50 meters they were attached by shoulders, which were buried into it.

These works had always a great development, as they protected only the parts against which they were constructed. They had no effect in protecting the localities either above or below the position they occupied.

233. *Their Duration.* This fascine work, executed entirely of ordinary fascines, could not have a greater life than that of the wood which composed it; that is to say, seven or eight years, but more often they were destroyed earlier by the repeated attacks of the river on the points menaced, which these works were called upon to protect.

234. *Their General Dimensions; Scour at Their Base.* This fascine work, when first built, was made 6 to 7 meters thick at the top; that is to say, at the level of the land. The wall toward the bank was vertical; on the river side the work had a slope of 45°.

These works were executed at mean waters and nearly parallel to the course of the Rhine. It resulted that the scouring, which must necessarily occur at the foot of the work, increased to a certain extent during construction without attaining its maximum depth which the first flood gave it. The fascine work then experienced a first settlement which the attachment of the shoulders built into the earth could not resist. If they had resisted this movement they would have produced a harmful effect, for the work after remaining suspended a certain time above the hole scoured out would not have failed to fall into it en masse and would thus have been more exposed to complete destruction. Instead of this the fascines by their flexibility followed the progress of the scouring, but without opposing it at all times; and it is in this that their effects differed essentially from riprap protection. The latter, formed of elements independent of one another, can slide with the supporting earth, but will still carpet the bottom of the excavations and thus contribute to diminish the effect of

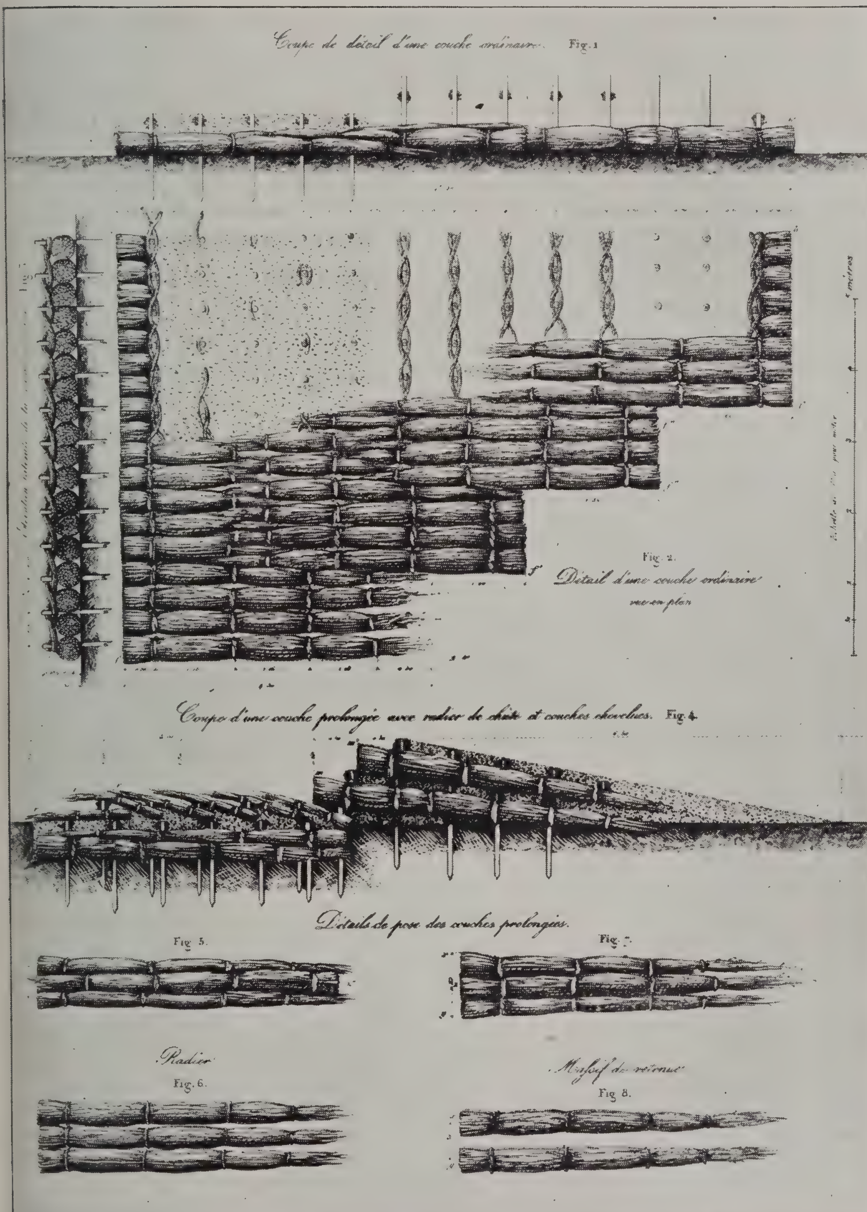
the causes which produce them. Also, as the resistant banks provoke more scouring than those which yield to the action of the river, it very often occurs that at the following flood, the scouring having become more pronounced, the fascine work attained a very steep slope, and that it finally became out of plumb and slid en masse into the excavation. The current then exerting itself between the work and the bank, the erosions became considerable, and instead of obtaining a means of protection, at considerable expense, one had often on the contrary given to the river a new means of attack which intensified the destructive action from which one wished to protect it.

235. *Mean Price Per Linear Meter.* The fascine work extended generally 8 meters below the stage and 2 meters above; that is to say, a total height of 10 meters was 6.50 meters thick at the top; and had an outer slope of 45° which produced, including 5 per cent for settlement and a second 5 per cent for maintenance during two or three years, a volume of ordinary fascines of 126.50 cubic meters per linear meter, which, at a mean price of 1.434 francs, costs 181.40 francs per linear meter of bank.

236. *Wing Dams for the Protection of the Bank.* The protection of the banks of the Rhine was thus carried on for a great number of years. As soon as one dike was carried away it was replaced by another. The expense was considerable, and the protection obtained was only precarious. It was for the purpose of substituting for the ephemeral and costly works a system economical and more durable in its results, that we had proposed and had executed wing dams for the protection of banks.

237. *Their Object.* Wing dams extending more or less into the bed of the river, have for their object to remove the principal current, by transferring it off-shore. By this means the lateral action of the currents, as well as their action in the river bed, are in some manner extended over a certain length of bank which the works are designed to protect.

288. *Their Disposition.* Different dispositions have been tried for the purpose of determining the best direction to give the wing dams in relation to the banks to be protected. The problem to be determined was, What would be the angle under which the greatest extent of bank could be protected with the same length of dike? There was first tried an angle of 135° upstream (Fig. 9, Plate LXV). Then it was thought that better results would be obtained by making this angle in an inverse direction; that is to say, downstream as indicated in Fig. 10, same plate.


Coupe de détail d'une couche ordinaire. Fig. 1
Fig. 2.
Détail d'une couche ordinaire
vue en plan
5 mètres
Coupe d'une couche prolongée avec radier de chûte et couches chevelues. Fig. 4
Détails de pose des couches prolongées.
Fig. 5
Fig. 7
Radier
Fig. 6
Massif de retenue
Fig. 8

Pl. L.

These opinions, so contrary, have caused us to include in our trial an intermediate disposition, the right angle. Besides, it has appeared to us that there is lacking on this subjest experience and observation. We have then (Fig. 8) placed the axis "*a-b*" of the dike perpendicular to the direction of the bank.

239. *General Results; Consequences of these Trials.* From the different dispositions there have resulted the following general effects. Eddies (see Figs. 8, 9, and 10, Plate LXV), have formed above the works, attacking the bank more or less as they have developed. This attack has had so much the less strength as the work had more inclination, and the angle above was more open. The current below at the point where it passed the head of the work has divided into two parts, the one the least considerable, followed r', and hit the bank at a distance below more or less great, according as the angle with the bank was more or less open. The other, forming the principal current, having been directed following t' toward the middle of the river, returned to the bank at m. In the space between the two currents, t' r', is found a gravel bar more or less raised; the distance at which the principal current, t', returned to the bank was so much the more increased and the extent of the gravel bar was so much the greater as the normal length of the salient work was more considerable. Two remarkable effects resulted, then, from the greater normal length of the salient work: diminution of the erosion of the bank above by the distance of the eddy from it; increase of the bank below by the distance of the point of meeting of the principal current with the bank. And as with equal volumes, the perpendicular direction is that which gives to salient works the greatest normal length, it is this disposition which we have preferred to all others for the protection of the banks of the Rhine.

240. *Inclined Salient Works; Same Perpendicular to the Banks.* By an inclination of 135°, whether in one way or the other, a salient work of 50 meters does not produce more effect than a perpendicular work of 35.5 meters, and when the spur is inclined upstream (Fig. 10) the erosions of the bank are greater and the bank formation less extended than when the inclination is downstream. (Fig. 9.)

The object of inclining the salient works in the direction of the current doubtless was to diminish the effect of the shock which was then almost proportional to the sine of the angle of incidence, and by this means it was probably proposed to reduce

the depth and the extent of the cavings. But this advantage was evidently compensated for by this consideration, that the spurs operated only by reason of their normal projection to the bank; it was a pure loss when one increased considerably the volume and expense of the work by adopting an oblique direction.

The inclination upstream, added in addition to this capital defect the disadvantage of diminishing a great deal the extent of the bar formation below without forming above a prism of dead water (see Note F) designed, as was assumed, to protect the bank.

When the salient works were submersible, the upstream eddies were the weaker as the submersion was greater whatever inclination was adopted, but in the case of an inclination obliquely downstream (Fig. 9) the overflow of the water was made to follow a direction perpendicular to the upper crest of the structure, and this action was carried on to the bank, which it tended to destroy with greater intensity than when there was no submersion.

Note F. Trial of Jetties Inclined Upstream. For the Durance it has been proposed to incline a little upstream the projecting works. It is pretended that there will be found then a pressure of dead water the length of the work in lieu of the currents which ordinarily there manifest themselves. The trial which has been made of this disposition could not be conclusive, since the application has been limited to the convex side of a bend of the Durance; that is to say, on the point where the alluvium tends to form and where the deposits must accumulate naturally and without the aid of any kind of work. In this location, the works were no longer works of protection but only an additional cause of accelerating deposits. In order that these works could be considered at the same time both as works for protection and as those for creating artificial deposits, it would be necessary that they be placed on the opposite bank, in the concave side of the bend; that is to say, at the location of erosions. It is in this position that one could have recognized, if the effect announced could be produced, and if the presence of dead water was found. After having examined these works, our opinion is that this pretended pressure of dead water had been replaced by an eddy attacking in flank the salient work and this notwithstanding the inclination in plan of this structure.

There is a serious objection to these works, if tried as we cite. There would not have been protected the concave parts of the two bends above and below the salient works with a convex projection at the structures and soon the water, in caving and developing more and more the concavities, would end by attacking the fill which separates them. The first salient work, notwithstanding its form and inclination, would then be destroyed as soon as attacked. The following work then taken in flank by the eddy above would soon experience great damage, and one can foresee that it would soon disappear with the fill on which it had been established. Rivers have thus a propensity to develop more and more at the expense of the banks, the bends which they form in their curvilinear parts. This action is especially strongly pronounced toward the lower part of each bend. There results in the course

of rivers a succession of true curves which the rivers describe by destroying vertical slices, the earth deposits situated at the summit of these inflections. Thus, as a first condition for the protection of the banks, it is necessary to first stop the caving of the bends, and without this condition one can not hope for any permanent advantage from works executed on the convex side.

241. *Protection of the Bank at the Abutment.* In every case, whatever be the direction given to the salient works, the banks must be protected near the abutment, *a*. Without this, by reason of the effect of erosions, the waters would establish a new channel between the bank and the work which, then far from protecting the bank, would become a cause of eroding it.

The salient works must also be protected against the eddies which wash them away and which soon cause their ruin. Layers of fascines and riprap have been tried without very pronounced success. The best way to destroy the upstream eddy is by replacing the scour by deposits by giving to the works the submersible devices explained in paragraph 255.

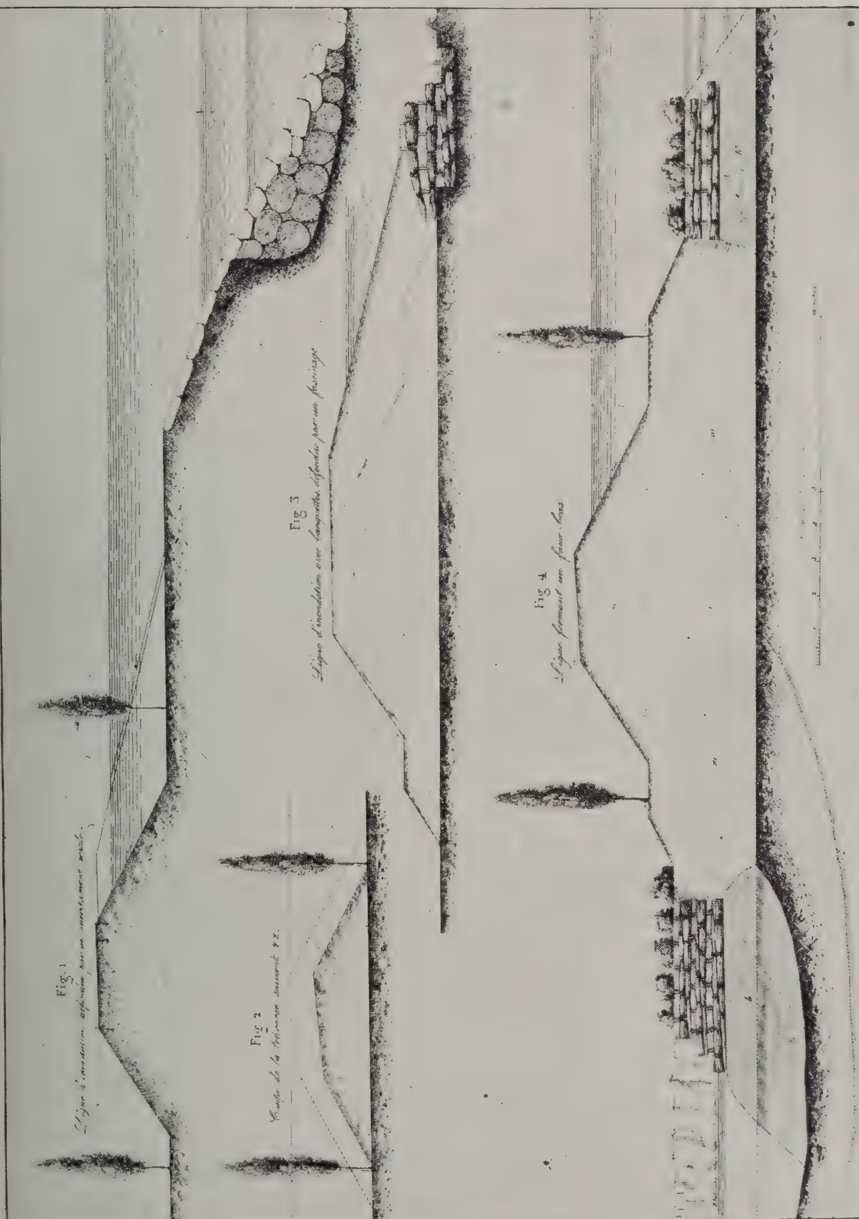
242. *Deposits Upstream; Deposits Still More Considerable Downstream.* Sufficiently often the deposits are formed at a certain distance above the works. This distance depends on the direction of the current, whose effects are combatted, and the extent of the eddies. The deposits below create along the bank a counter current which often provokes erosions sufficiently pronounced, and it was necessary to remedy this either by mixed riprap or by small submersible sills (a' b' c', Fig. 8), the object of which is to attach the deposits, e e', to the bank. These little works of very small height facilitate the deposits by deadening the current and destroying at the same time the effects of the eddies, r'.

After having determined to adopt exclusively for the spurs a direction normal to the banks, our studies have been directed toward the process to be employed to diminish as much as possible the effects of the upstream eddies, which are the most dangerous and which often compromise so gravely the existence of the works.

243. *Details of a Perpendicular Dike.* The form of wing dam called perpendicular dike, and constructed on the Rhine for the protection of its banks, is represented by Fig. 4, Plate LXVII.

[Further details are omitted.]

246. *Effects of the Dikes Constructed.* A sufficiently large number of perpendicular dikes of forms and dimensions similar to those which have just been described, have been constructed for the



Pl. LI.

protection of banks in different localities. These works have nearly always produced the following effects and results: Eddies r, r', r'', up and down stream; modifications of the principal current t, following the direction t' t''; banks of gravel c c' more or less raised; this elevation was proportional to the scouring effected upstream at the head of the dike. The bank of gravel was nearer to the mass, a a' b b', when the dike was terminated at its extremity by an inclined edge instead of presenting a circular line, and as by this first disposition the slope (2), Z, was more salient downstream. In this case, the current c'' was weaker and the eddy r' less considerable.

247. *Upstream Deposit.* When the dike was located so as only to attain the thalweg at two-thirds of the projection from the bank at the time of its construction, and at an inclination of 130° to 135°, there is formed upstream at about 60 meters from the dike a second bank of gravel, produced by the diminution of the velocity which caused the effects of the upstream eddy.

248. *Length of Bank Protected by the Dike.* In the case the most favorable, when the bed of gravel downstream was attached to the river bank by means of a small sill of ordinary fascines, the dike protected a line of bank almost equal to five times the projection of the work.

249. *Works of This Kind Have Very Little Duration.* None of the dikes constructed, even with the precautions which have been indicated, have existed for more than three or four years. The layer on which they have been primarily placed has been unable to sufficiently protect against the erosions which have occurred as well upstream as at the head of the dikes, because the slope could not be sufficiently extended. The caving becoming considerable, the dikes have not failed to break along the line m m', or almost one-third of their length from the bank, after having strongly settled both above and below, or in the direction of their axes.

250. *The Dikes Which Exist Have For A Long Time Been Exempt from the Attacks of the River.* Some perpendicular dikes still exist, but under circumstances peculiar and foreign to the effects which they were called upon to produce. The principal course of the river has abandoned, some time after their construction, the chutes in which they had been constructed; and if the principal course of the river still exists in the same bed, its action is transferred further downstream by reason of erosions acting in

cavities situated on the opposite bank above the dike, so that the dike is beyond the destructive action of the thalweg. In all other circumstances, the perpendicular dikes have only a short life and the deposits formed by these dikes have disappeared with the parts of the work which have determined their formation.

251. *Mean Cost of a Dike.* A perpendicular dike of the dimensions previously described, costs generally 52,600 francs; the length of the bank protected in the most favorable case, that of a cavity of a sufficiently pronounced curvature is 300 meters, which makes the mean cost of protecting a linear meter of bank 175 francs. This sum is considerable, if one recalls the temporary results which are obtained.

252. *The Projection of the Dikes is Very Limited.* It is to be observed that the perpendicular dikes were very limited in the length of their projection; that they would very rarely be extended into the river more than 45 to 50 meters, constructed by the method of ordinary fascines; they caused, when at this distance from the banks, depths almost always excessive, which have been in some cases as much as 25 meters below low water, so that with this system it was necessary to abandon forcing the thalweg of the river to more than 50 meters from the bank.

253. *Weir Dikes.* To find the means to destroy the upstream eddies, and to be able to give such projection as one wished to the perpendicular dikes without increasing more in one case than in another the scourings at the head of the works, was then a very desirable amelioration in the works of the Rhine, and it is that which has been obtained by means of weir dikes constructed in part of riprap, of wicker work, and of gabions terminated by means of ordinary fascine work and then revetted, on the slope exposed to the current, by a layer of large rough dressed stone.

254. *Unlimited Projection of Weir Dikes.* It is this innovation of riprap with gabions and wicker work which, by permitting us in this new series of works, as in closing dikes, to protect the scoured bed by the riprap in large fascines and wicker work, has lead us to try these weir dikes represented in detail in Figs. 1, 2, and 3, Plate LXVII. The weir dike, which we gave as an example, projects only 60 meters, but the explanation of the system of construction applied to this work well demonstrates that this projection can have such an extent as is desired. This system of dikes was tried on the arm Mabile, and then on the Great Rhine at Lobstein, Woerth, and near Strassbourg.

255. *The Weir Dikes Induce Upstream Deposits Instead of Eddies.* It is evident that if a dam is placed below the upper opening of a chute which it is necessary to close, and if this dam is submersible or in part submersible, there will not be found upstream eddies, and in place of a scour there will be a deposit. This property belongs to the submersibility of the work. The waters are retarded in their movement only by an amount necessary for them to abandon a portion of the material which they have in suspension. They then flow off to make place for new waters carrying material in suspension.

In combining projecting works so as to give them the same properties, one must necessarily have deposits where, according to old methods previously practiced with spurs, there was scouring.

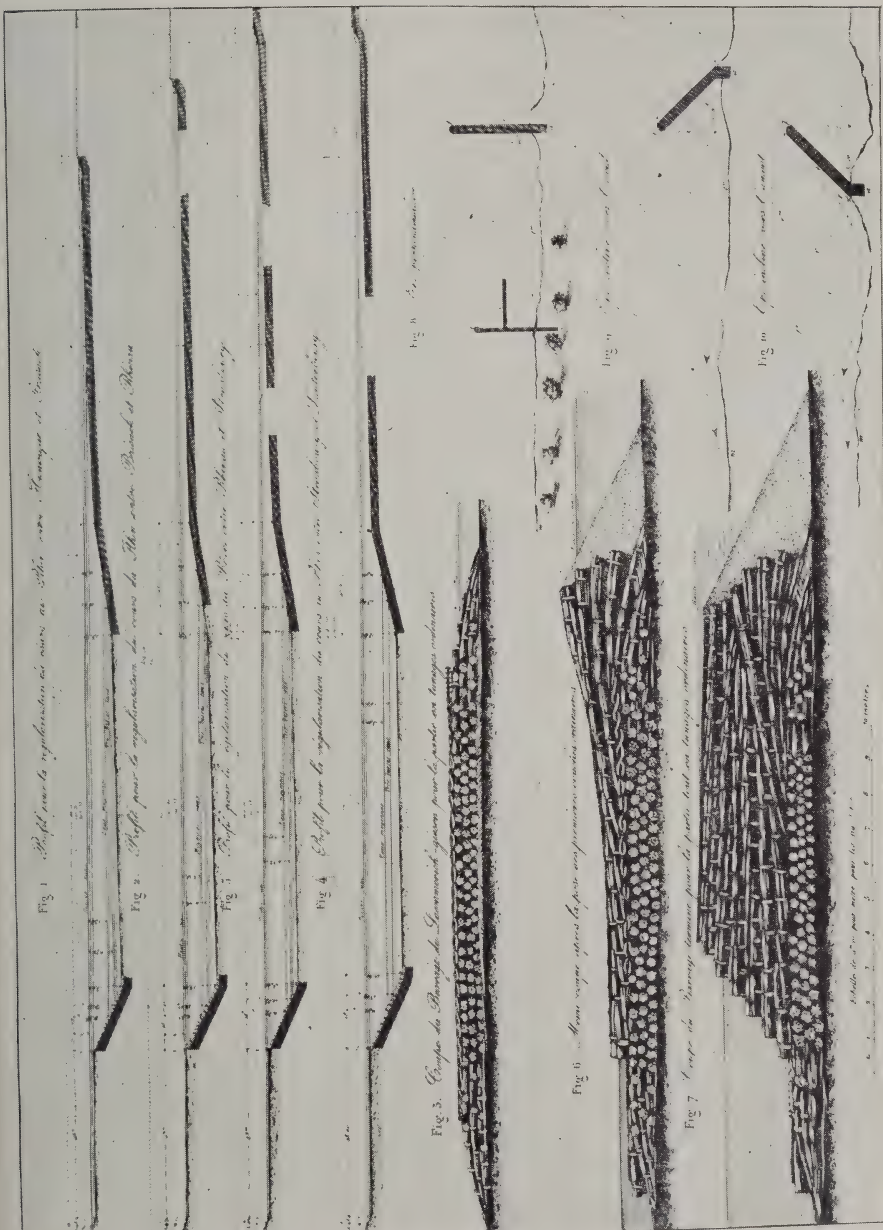
257. *Weir Dikes Will Be Of Great Assistance for Regulating the Course of the River.* The method of construction of a weir dike is independent of the length to be given it or of the position of the mass *d m*, since this mass by means of a system of riprap can be established at any part of the river current. It is only necessary that the development given to the work be in harmony with its projection, and with the importance of the chute in which it is placed.

In conclusion, every time a chute can not be completely closed, the weir dike will be of great assistance for regulating the course of the river, by displacing the thalweg, placing it at a great distance from the bank attacked when either convenient or necessary.

258. *Mixed Riprap.* We have seen that the spurs of ordinary fascines were ordinarily employed for the protection of banks and that this was almost the only kind of material of which these works were composed. We have shown the inconvenience, and estimated, in mean terms, the expense at 181.40 francs per linear meter.

We have replaced the fascine spurs by a system of mixed riprap infinitely preferable, as much on account of its duration as of its expense. For a linear meter of mixed riprap with an almost indefinite life, will cost under the same circumstances only 126.17 francs, which represents a difference to the advantage of the mixed riprap of 55.23 francs, or more than 30 per cent.

259. *Details of Mixed Riprap.* The protection of banks by mixed riprap is effected, first, by means of a mass *d*, Fig. 3, Plate LXVI, composed of a certain number of gabions of four meters in length and 0.80 meter in diameter at the middle, constructed as formerly



Pl. LXV.

explained (125), and which are anchored at the foot of the slope of the bank by means of an equipment constructed as shown in Figs. 1 and 2, same plate, with this difference, that the bascule bridge is not necessary. The gabion is rolled on the apron, *c a*, and cast into the water, having its axis parallel to the bank, as can be seen in the profile, Fig. 1, Plate LI. The material deposited is placed in such a manner as to give to the slope of the mass formed by the gabions three of base to one of height, so that notwithstanding the scouring carried on at the foot and after the settlement of the work has attained its maximum, there still remains a slope of two of base to one of height. The same equipment serves also to deposit on the side the prismatic wicker work intended to form the foot of the slope, so that the sliding of the riprap will be more uniform.

260. *The Slope is Covered with a Layer of Large Stone.* When it is assumed that the scourings and settlement have attained their limits, of which one can judge from the soundings taken every 20 meters after each flood, and when the certainty of the stability of the mass has been assured, on the deposits of the very hard and compact sediment which then covers the slope is constructed the revetment of larger stones which protects the wood from the action of the water, and give to the work a life as long as that of the rock. For the wood is here only as a means of producing mass, of maintaining the gravel of the fill to the time of revetting the slope with large stone. Besides, under the assumption of a riprap entirely of large stones, the volume of rock employed would be 30.06 meters and the cost would be raised to 262.12 francs, or to more than twice the cost of mixed riprap composed of wicker work, gabions, and large stones.

261. *Deposit of Large Stone.* In order that the deposit of the large stone intended for the revetment of the slope of the mixed riprap be made in a regular manner, the same equipment is used as for the deposit of the gabions intended to form the first part of the riprap, to which is added a small service bridge of a width of 1.50 meters, composed of two strong balks of timber scantling proportional to the distance from the boat to the bank, and equipped with planks of a thickness of 0.06 meter graduated along their length every 0.25 meter, so as to serve as reference marks for the immersion of the stone.

The stone is carried on hand barrows and immersed to the line of the numbers of the graduations. Then the bridge is advanced along

the bank the width of the slice that has just been riprapped, and the deposit of the following slice proceeds in the same manner. By this means the enrockment is executed uniformly on the entire surface of the slope in both directions and with an equal thickness. This operation is also controlled by the numerous soundings which have been taken on the site at each position of the service bridge. Care is taken to double the thickness of the revetment toward the bottom, so that the scour which takes place can be immediately filled without the slope having to suffer.

262. *The Banks Above the Riprap are Revetted with Stone Packing.* The revetment with large stones is carried to about 1.30 meters above mean water. On a higher level, the bank *a b* is flattened and dressed to a slope of two of base to one of height and covered with flat stone of about 0.16 meter in thickness, presenting the greatest surface possible.

263. *Willows Are Planted to Consolidate These Revetments.* Willows are then planted in the joints of the flat stones of the revetment, their young growth by their flexibility diminishes the velocity of the water and provokes the sanding of the surface eroded. This wood, cut each year with the successive growth, finally produces such a thickness of sand that any degradation becomes almost impossible.

Such is the composition of the system of mixed riprap which we have substituted for spurs of ordinary fascines. We have obtained the most satisfactory results from them.

264. *Enrocked Mats.* A last system of protection has also been employed with sufficient success when it was a question of keeping the principal current of the river a distance of from 25 to 30 meters from the bank, while preserving a direction nearly parallel to it. We refer to "*Tapis Enroches,*" represented in Figs. 1, 2, and 3, Plate LXVIII. These works form in some manner a kind of detached riprap of gentle slope toward the river. These mats have in this last respect a quality which one must seek above all else in works of protection, that of offering in order to destroy the caving not only submersibility, but also the gentlest inclination possible. In the mixed riprap it has been necessary, on account of the expense, to limit the slope to two of base to one of height. By the construction of riprapped mats this slope could be reduced one-half; that is to say, to four of base to one of height.

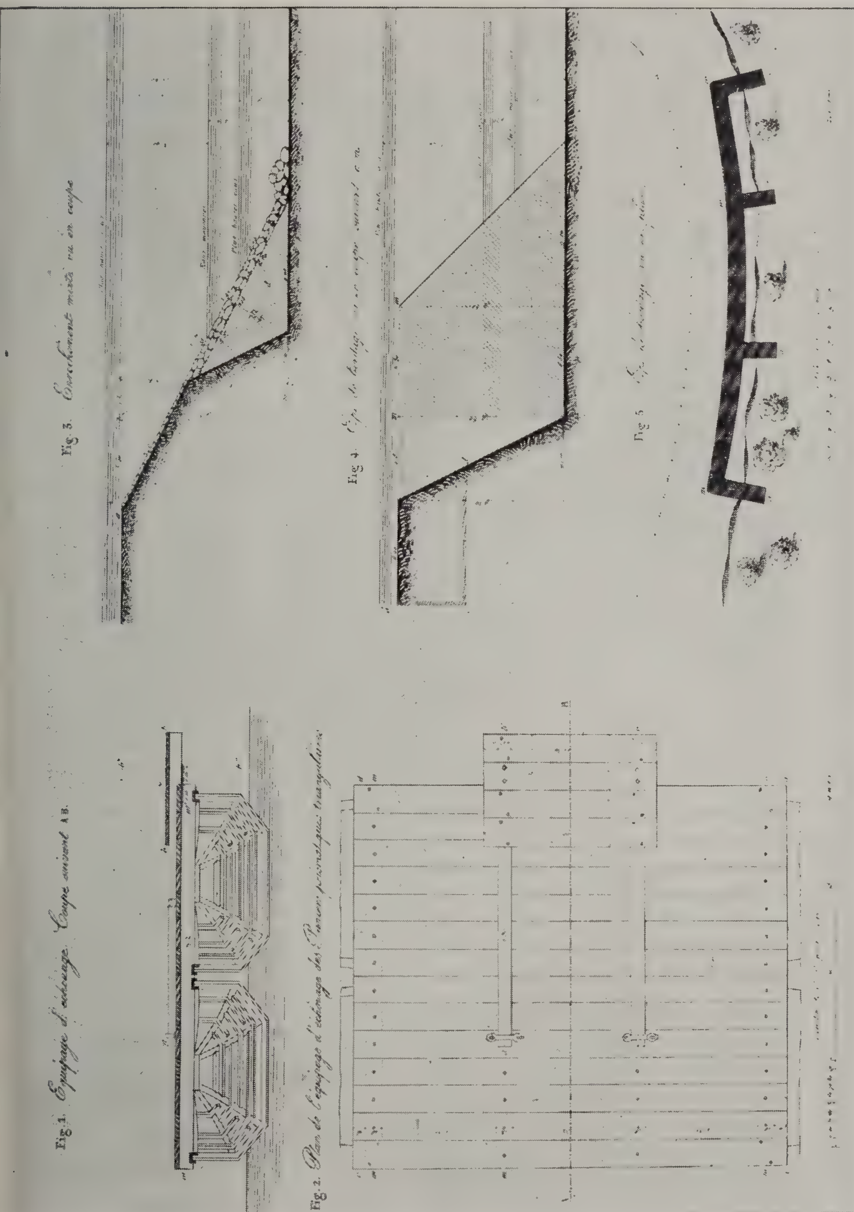
267. *Size of the Stone; their Specific Gravity.* The large stone and ashlar, employed for mixed riprap, have generally a volume

0.043 to 0.050 cubic meter. Their specific gravity is generally 2.245, that of water being taken as unity.

268. *Particular Form of the Mat.* The mat was first given a triangular form, but the downstream current was carried almost immediately onto the bank. By giving to the end of these works the rounded form $a''' \ b'''$, Fig. 1, the current is carried further downstream and the bank is protected for a greater length.

269. *Application of the Different Systems for the Protection of Banks.* Such are the different kinds of work which one can employ for the protection of banks and which present, as has been shown, differences sufficiently appreciable in the price per linear meter of bank protected by the different systems. The choice to be made between the different methods will depend on the object proposed. When the bank to be protected is in the alignment adopted for protection from erosion, mixed riprap will be employed. When it is only a question of removing the river current from 25 to 30 meters from the bank, enrocked mats are constructed, of which the spacing varies according to the more or less curved direction of the bank.

When it is necessary to remove the river to a very great distance from an indentation too concave, we have recourse to weir dikes.



Pl. LXVI.

Taking Cross-Sections, Humboldt Jetties, California.

BY

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Assistant Engineer; Assoc. M. Am. Soc. C. E.

The Humboldt Jetties are at the entrance to Humboldt Bay, California, which bay is situated about 220 miles north of San Francisco and 325 miles south of mouth of Columbia River. Humboldt Bay is 14 miles long and from ⅜ to 3½ miles wide, with its longer dimension parallel to the coast, from which it is separated by low sand spits from ½ to 1 mile in width.

The entrance channel enters the bay through the only opening in the spits, at a point about 2½ miles south of the central portion of the bay. To improve this channel two parallel jetties, about 2,100 feet apart, were built seaward, from the point of each spit along either side of the bar or entrance channel, for 1 mile approximately, and in a direction nearly perpendicular to the general trend of the littoral in this vicinity.

The jetties were finished in 1899, and Congress not having provided funds for the maintenance of these completed structures, the jetties were eventually depressed to elevations varying from low water to 17 and 31 feet below datum at their outer ends, which deterioration of the jetties soon caused the entrance channel to revert, from the highly improved and satisfactory condition that had resulted upon completion of the work in 1899, to its original inferior and unserviceable condition for navigation.

The original jetty construction was done by the well-known "trestle method," using 10 tons as the maximum weight of stones.

In 1911, the preliminary steps were taken to begin the rebuilding of both jetties in a more substantial form, using as a maximum size 20-ton stones, and placing this heavier designed structure carefully by crane (17-foot gauge) operating on a concrete cap.

No better description of the roughness of the ocean at this bar

can be given than by quoting the report of (at that time) Maj. W. W. Harts (now Lieutenant Colonel, Corps of Engineers, U. S. Army), former District Engineer Officer, which description has been taken from report of Chief of Engineers for 1908, as follows:

> It has been reported by masters of steam vessels, that no such heavy seas are encountered elsewhere in the world, unless perhaps, south of Cape of Good Hope and Cape Horn. Waves have been seen to break in 8 to 10 fathoms' depth. It was originally believed that no jetties or other such construction . . . could possibly withstand the forces brought to bear by the waves during storms, so that the improvement of this Bar was undertaken with many misgivings.

In the prosecution of this reconstruction work, it is very essential to follow carefully the submerged enrockment of old jetty, so as to provide a substantial berm of stone at toe of slope, especially on the deeper or *channel* side, which at the north jetty is the *stormy* side. In order to do this with the best alignment, it is necessary to take cross-sections regularly, ahead as far as practicable; and to furnish cross-sections of completed enrockment, at every 100-foot station, at least.

Previously, this work had been done by use of rowboats and tag line, the usual method; but, owing to a quite constant sea condition, for long periods, that would not permit of this work being done with any degree of accuracy nor safety, the necessary cross-sections were frequently missing from the records for as long a distance as 4 or 5 stations; and, consequently, the alignment of rebuilt jetty was, at times, not the best with reference to the foundation beneath. At least, the old method of doing this work proved uncertain, slow and expensive, because three small boats had to be used and brought out a distance of several miles from the receiving wharf on the bay side. Frequently these trips were made for naught, and lives endangered by the sea, which "picks up" quickly even in time of best weather.

This method of taking cross-section for jetty construction was improved upon by utilizing the crane that is used for placing stone in jetty. This crane is a revolving, self-propelling crane of 700 foot-tons capacity, using from 35 to 50 feet radius of boom. For taking cross-sections the boom of crane is made to support horizontally a very light wooden "outrigger" platform, which is suspended by means of old ⅝-inch diameter wire ropes in the manner shown in Fig. 1. The horizontal "sway-guys" are made of one strand each from a six-strand ⅝-inch diameter plough-steel cable, and are rigged as shown in sketch "B."

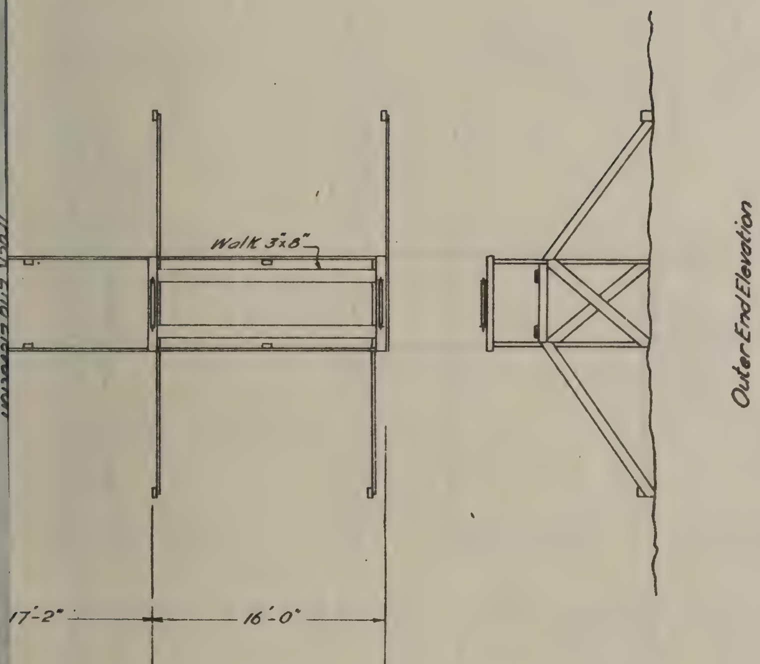
This platform reaches out 128 feet from center of crane, and is itself 120 feet in length. Measuring from the center of crane, which coincides with the crane tracks and concrete cap, the platform is marked in 10-foot stations. The height of platform is constant above jetty cap, which is built level transversely, and generally level in profile.

This outfit was first used, during June, 1915, to take cross-sections of the south jetty, then just completed.

The lumber used therefor is of No. 2 common Oregon pine, as follows: 3 by 4 inch sills, which are scarfed and bolted to form two

Fig. 1.

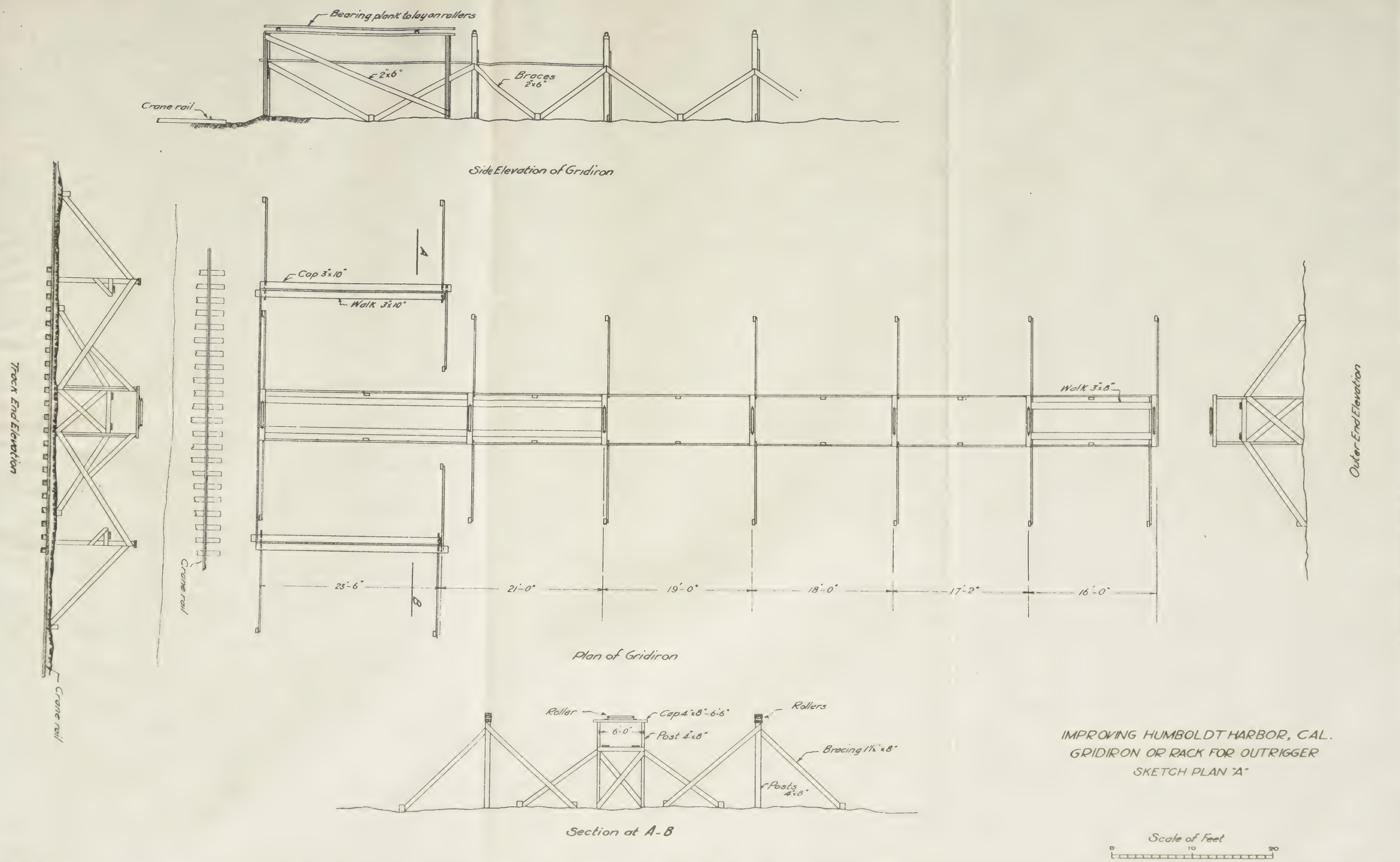
through stringers laid about 24 inches apart; upon these are nailed transversely 1 by 3 inch battens, over which are placed 1 by 8 inch boards laid horizontally for a walk; and posts of $2'' \times 4'' \times 3.1'$ spaced about 15 feet apart on either side of the walk, through the top of which are ¾-inch diameter manila ropes, drawn taut, to serve as hand-rails. To prevent swaying, a piece of timber $6'' \times 10'' \times 46'\ 0''$ is used as a horizontal brace and attached to stem of platform, to which it is fastened at right angles, and, when the "outrigger" is to be used, is made fast by bolts through this brace to the front of upper body of crane. To this timber brace several horizontal wire guys are fastened taut to various points on the stringers or sills of platform, as shown in plan "B" herewith.



IMPROVING HUMBOLDT HARBOR, CAL.
GRIDIRON OR RACK FOR OUTRIGGER
SKETCH PLAN "A"

Scale of Feet
0 10 20

C.M.R.P.



IMPROVING HUMBOLDT HARBOR, CAL.
GRIDIRON OR RACK FOR OUTRIGGER
SKETCH PLAN "A"

A profile of cap of jetty is accurately kept, and cross-sections are taken of completed structure from time to time, at the required stations. The elevations of these cross-sections are taken with a lead-line measuring from the floor of platform to enrockment above and below water. The distances on the platform from the center-line of concrete cap, or crane-way, are marked 10 feet apart.

The platform, when attached for service, is tested as to its uniform elevation, before and after using, by turning it over a level stretch of cap; or, if more convenient, by use of vertical offset from height of instrument. Occasionally there is a slight ascending grade seaward to which the platform is adjusted by level, so as to swing the required arc with a minimum variation from the horizontal plane, which variation would be of no practical value when applied to this class of cross-section.

Fig. 2.

To facilitate correct and ready adjustment to its proper horizontal position, the platform, when not in use, rests upon a "grid-iron" which has been erected level at the correct horizontal and vertical distances from the crane tracks at their shore end, which tracks are level in profile and cross-section at this particular place.

Sometimes the outrigger is slightly out of level, due to stretching here and there of supporting cables, which data are noted. In plotting the sections thus taken, the center height of sounding platform is plotted first and platform, with its varying elevations, drawn thereon, using a template of bristol-board, quickly cut out to correct scale and form, from which line the vertical offsets to jetty

and bottom below are readily plotted by means of a short scale. One-half foot has been the maximum variation of outrigger from a horizontal plane, which error is readily corrected by adjustment of the vertical guys, before using the "platform" another time.

For locating the submerged old jetty enrockment ahead of construction, and for taking borings through the sand blanket over the old stone, this outfit is especially suited.

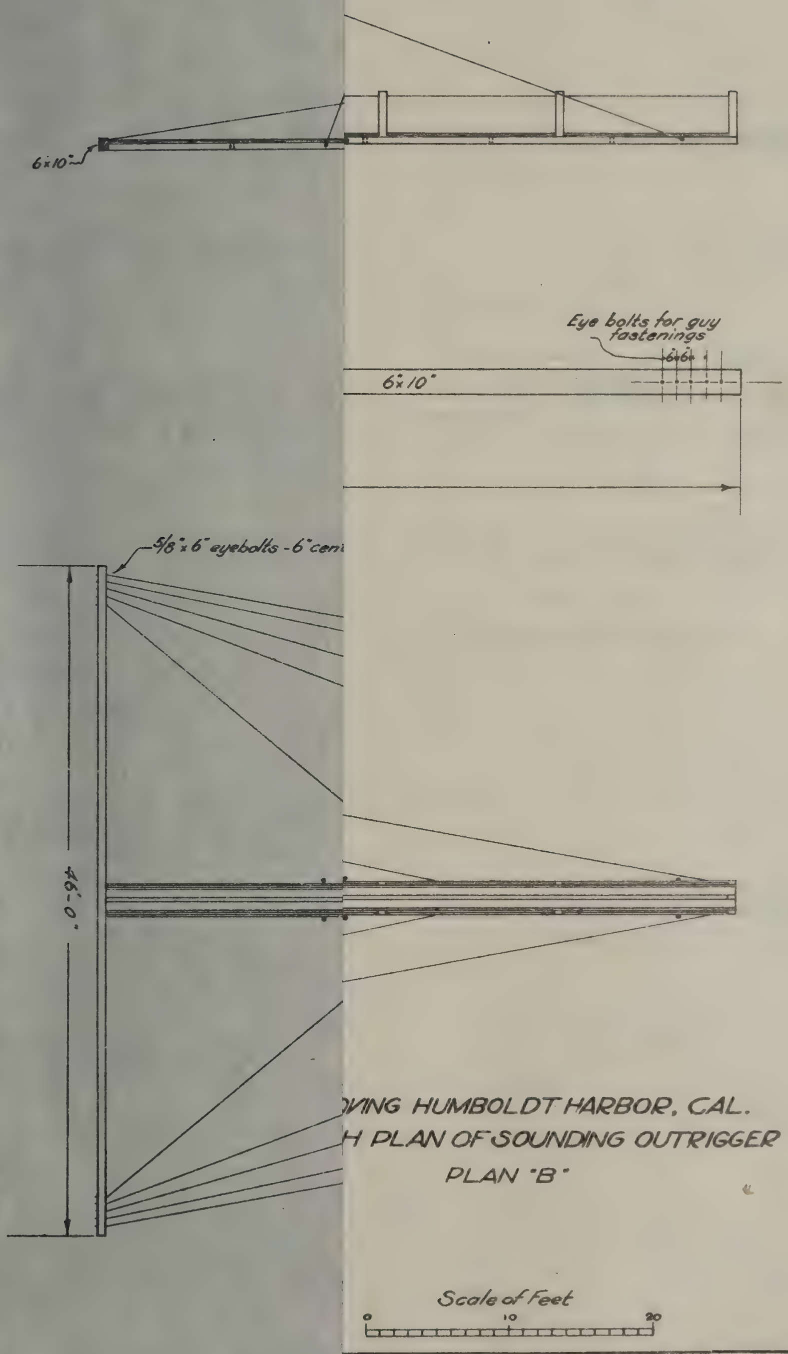
The cross-sections are taken as shown in plan "C." The positions of end of platform (where the leadsman is stationed) and center of crane, for each sounding 10 feet apart, for cross-sections taken ahead of jetty construction, are shown in plan "C." The end of platform is placed by means of deflections turned by transit from a fixed station near end of jetty when the seas are not too heavy; or by an improvised "horizontal circle" painted on lower body of crane where the "graduations" are visible from the platform above, for use in stormy weather. The corresponding position of crane, for each sounding, is marked with paint on the cap below. Cross-sections of finished structure are taken by placing the platform, full length, over the section to be taken.

The crest of the old enrockment, to its end, is indicated by buoys made in the most substantial manner. These are located by instruments and plotted on a large-scale working map. As the jetty is extended, its location is plotted and compared with the alignment of crest of old enrockment as revealed by the cross-section just taken and positions of the buoys ahead. This procedure is necessary to prevent unnecessary changes and to make the best general alignment.

Ordinary cross-sections, 250 feet wide, with not less than 24 soundings, have been taken, using a 14-pound lead in rough "weather," in 45 minutes. To attach and adjust the outrigger for service, 20 minutes time is sufficient; and about the same time is necessary to take off and to store the platform on its rack or "gridiron."

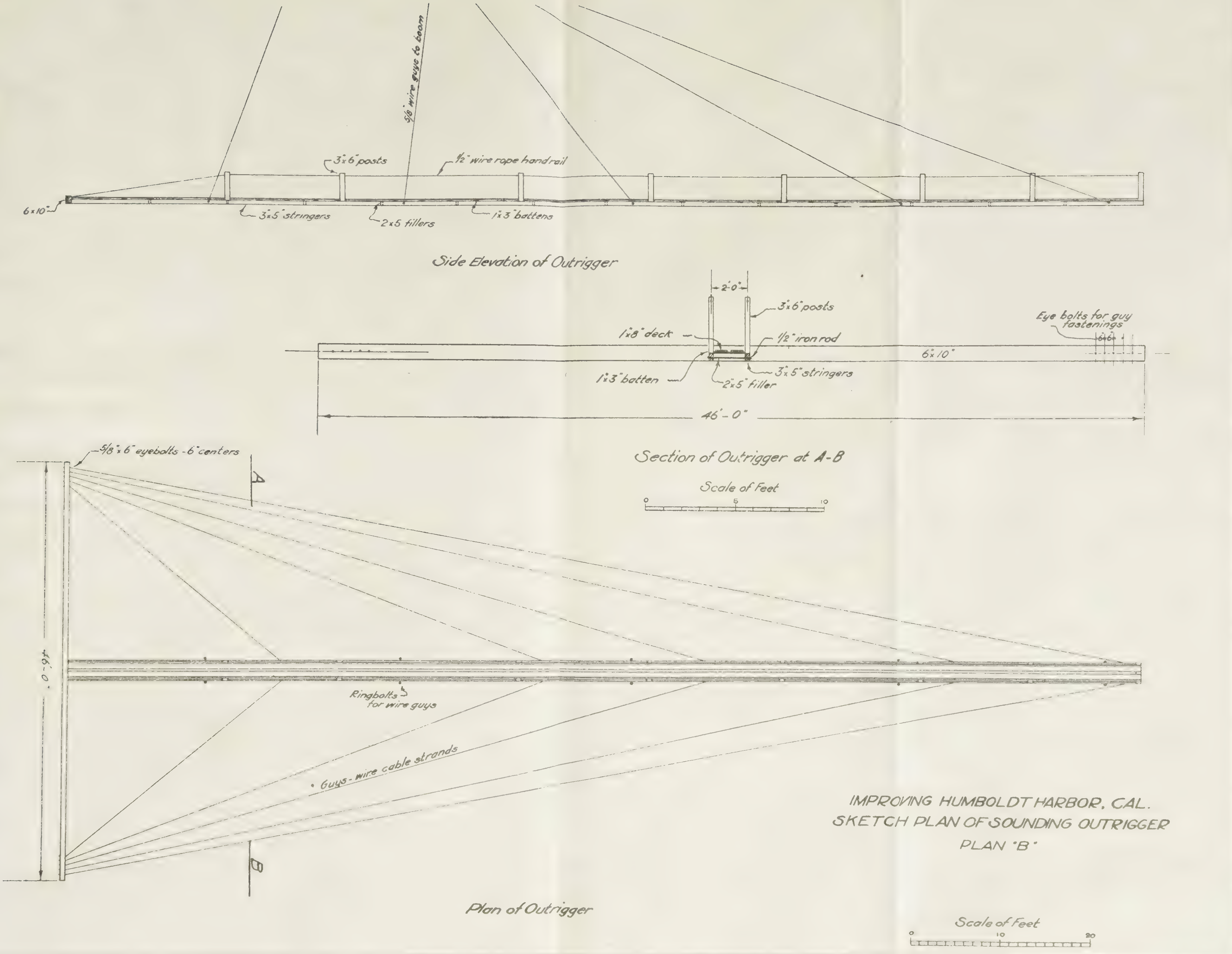
The crane travels at a rate of 2 miles per hour, and therefore can make the round-trip from gridiron to jetty end in 50 minutes, if there are no obstructions.

When taking cross-sections ahead of construction, with this outfit, the following are used: 1 engineer, to operate crane, at $4.50 per diem; 1 fireman, on crane, at $2.50; 1 leadsman, on platform, at $3.00; 1 recorder, on platform, at $77.50 per month; and 1 transitman, on cap, at $83.33; total crew, 5 men.



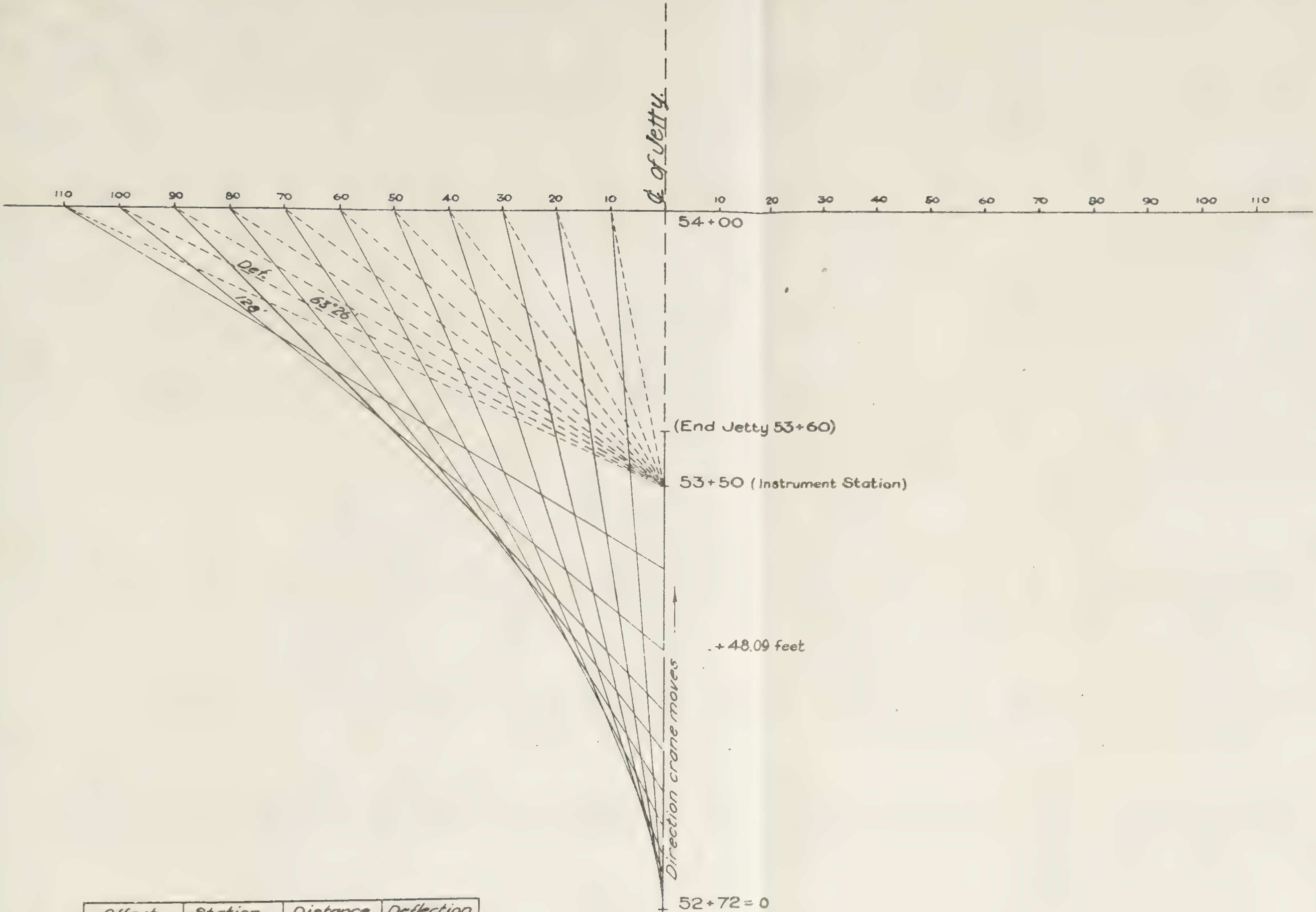
6x10"
Eye bolts for guy fastenings
6 6
6x10"
5/8"x6" eyebolts - 6" cen
46'-0"
VING HUMBOLDT HARBOR, CAL.
H PLAN OF SOUNDING OUTRIGGER
PLAN "B"
Scale of Feet
0
10
20

C.M.R.P.



IMPROVING HUMBOLDT HARBOR, CAL.
SKETCH PLAN OF SOUNDING OUTRIGGER
PLAN "B"

C.M.R.P.



Offset	Station	Distance	Deflection
0 from ℄	Sta. 52+72	128 feet	0°00'
10 "	+ 0.46	" "	11°19'
20 "	+ 1.49	" "	21°48'
30 "	+ 3.56	" "	30°58'
40 "	+ 6.46	" "	38°40'
50 "	+ 10.21	" "	45°00'
60 "	+ 14.93	" "	50°12'
70 "	+ 21.83	" "	54°28'
80 "	+ 28.08	" "	58°00'
90 "	+ 37.00	" "	60°57'
100 "	+ 48.09	" "	63°26'
110 "	+ 62.56	" "	65°23'

IMPROVING HUMBOLDT HARBOR, CAL.
SKETCH SHOWING METHOD OF SOUNDING WITH CRANE AND OUTRIGGER

PLAN "C"

Scale of Feet

0 10 20 30 40 50 60

About eight cross-sections are taken in one "shift" of 8 hours in ordinary weather, and the cost thereof for labor is about $2.00 the section.

The "gridiron," used for storing this platform, is 120 feet long, or about the length of outrigger itself (see sketch, plan "A" and Fig. 2).

The component parts of this gridiron are as follows: Height from ground to top of rollers, 11 feet (average); 7 bents with 2 posts, each 4 by 8 inches, and set firmly in sand about 5 feet apart; caps 4 by 8 inches and with each bent sway braced with 2 by 6 inch boards, and well braced, longitudinally, as shown in Fig. 2. On the cap of each bent is placed a 2-inch diameter pipe roller, 30 inches long, with wooden core.

Upon these rollers the platform, when detached, is moved by hand to clear the tracks or back again to upper frame of crane, as needed.

The principal materials forming this gridiron were: Rough Oregon pine, 570 linear feet 1 inch by 6 inch; 120 feet 2 inch by 6 inch; 12 feet 2 inch by 8 inch; 120 feet 3 inch by 10 inch; 120 feet 3 inch by 12 inch; 430 feet 4 inch by 8 inch.

The costs of the gridiron were: For lumber, $28.50; for labor, $34.50; miscellaneous, $12.10; total, $75.10.

The principal materials used in making the outrigger were: Rough Oregon pine, 280 linear feet 3 inch by 4 inch; 200 feet 2 inch by 4 inch; 360 feet 1 inch by 8 inch; 140 feet 1 inch by 3 inch; ⅝ inch wire cable, 220 linear feet; ¾ inch manilla rope, 250 feet; costing for lumber, $11.34; for cables (no value); for rope, $5.60; for labor, $28.17; miscellaneous, $10.50; total, $55.61.

The total cost of the outfit, complete, was: For gridiron, $75.10; for outrigger, $55.61; total, $130.71.

The sounding platform was quickly planned and hurriedly built in two days from materials on hand; consequently, it is not properly proportioned. However, it has now well served for 16 months the purpose for which it was intended, and with practically no repairs.

This work is in charge of Col. Thos. H. Rees, Corps of Engineers, District and Division Engineer Officer since 1911, and the writer has been resident engineer since the unfortunate accident and untimely death on April 17, 1915, of Mr. Morton L. Tower, M. Am. Soc. C. E., Assistant Engineer, who started this project in the spring of 1911.

German Methods of Trench Warfare.

GERMAN SYSTEM OF DEFENSE.

1. Throughout the whole of the front in France and Belgium the German system of defence consists of two or three fortified lines at an interval of, approximately, 2,000 yards.

The front line is, of course, continuous, and it comprises trenches for the firing line and for the supports. In it are situated bomb stores, pioneer advanced depots, etc., advanced telephone stations, and company commander's dug-outs. Sketches of a typical section of front line are attached (Appendices 1 and 2).

The second line of trenches is, normally, continuous, but not invariably so. For instance, in the vicinity of the Somme, until quite recently, the second line comprised only a number of detached posts. Similarly also, south of the La Bassée Canal there was only a single line of entrenchments until March, 1915.

Where the Germans anticipate pressure or any attempt at breaking through, the second line is made practically a replica of the first line. It comprises trenches for the firing line and supports, is protected by wire obstacles and has machine gun emplacements ready for use, although generally not manned.

The third line of defence is not normal for the French and Belgian area, but it is found at points of importance and, where it exists, is not necessarily of a continuous line, but there are always a certain number of reserve positions at intervals of 3 to 4 kilometers, or less.

GERMAN TRENCHES.

Details of the German trenches have been issued from time to time. They do not differ widely from our own trenches, but they are slightly deeper, slightly narrower, and the dug-outs are almost universally very well constructed.

The trenches vary according to the nature of the ground, the water level, and the ideas of the G. O.s C. divisions and corps, and of their chief engineers. As a rule they are 8 to 10 feet in depth. measuring from the top of the parapet to the bottom of the trench.

Another feature is the careful attention paid to drainage. The

floor of the trenches generally consists of ladder-work boarding, fitted in about 1′ 0″ to 1′ 6″ above the bottom of the trench, thus allowing the water to collect and, whenever possible, flow under the boards. This applies both to fire and communication trenches. A liberal supply of pumps is provided.

Planks are used to a considerable extent for revetting work, especially in the communication trenches. Rabbit wire is also a favorite form of revetment, chiefly in the front line trenches.

The Germans are fond of using sandbags of various colors, a good method of hiding loopholes.

Wherever the ground admits of it the dug-outs are made very deep. No dug-out is considered suitable unless the roof of it is at least 16 feet below the surface of the ground.

Information recently received shows that, when the nature of the ground prevents dug-outs being made to this depth, reinforced concrete is now being used.

The Germans make considerable use of ruses in their trench warfare. Numerous dummy machine gun emplacements are made with great skill. Generally without being so conspicuous as to attract suspicion, they are still more in evidence than the emplacements which are manned. Emplacements which are manned are almost invariably concealed, either by a canvas screen or by a hinged horizontal plate which falls down vertically when the machine gun is not in use.

The machine gun is the principal weapon of defence of the Germans, and they have undoubtedly acquired great skill in the tactics and handling of this arm.

The Germans often have a certain number of field guns in position, either actually in the front line trenches or close behind them for use against assaulting infantry only, or also for the purpose of enfilading sections of their own trenches which they think may fall into the hands of the British.

OBSTACLES.

2. The front line trenches are almost invariably protected by strong wire obstacles, usually with the inside edge of the obstacle about 5 yards from the parapet. The wire is generally about 10 to 20 yards in width.

High and low wire entanglements, chevaux-de-frise, French wire, and the concertina type are all met with.

Formerly wooden pickets were invariably used for wire en-

tanglements, but latterly these have been replaced by iron screw-in standards, which are more durable, noiseless to fix in the ground, and easily removed.

A number of narrow passages are generally left in the entanglement to admit of patrols passing in and out.

LISTENING POSTS.

3. Listening posts are generally put forward by the Germans 25 to 50 yards from their front line trenches. Listening posts are usually empty by day and occupied by night. They are almost always protected by wire.

METHOD OF HOLDING TRENCHES.

4. Generally speaking, the German trenches are very lightly held by day and in considerable strength by night. The men are supposed to get their rest and sleep in the day.

The garrison is either organized by battalions or by regiments.

EXAMPLES OF GERMAN METHODS.

	(A.)	(B.)	
Rest billets	A battalion	A battalion	
Supports	B battalion	□ 2 cos. □ B battalion	□ 2 cos. □ C battalion
Front line	C battalion	□ 2 cos. □ B battalion	□ 2 cos. □ C battalion

The choice between these and other methods is apparently left to divisions. It is not unusual to find two divisions of the same corps adopting different methods.

The normal infantry brigade organization of two regiments is tending to disappear in the German Army. German divisions now often comprise three infantry regiments in one brigade, plus the divisional artillery.

The normal frontage for a company is 400 to 500 yards, the average trench strength being 150 to 200 men.

Rest billets are generally 4-6 miles behind the front line trenches.

GERMAN METHOD OF DEFENCE.

5. Generally speaking, it may be said that the chief German method of defence is by sharp and effective counter-attack. The system of defence is arranged so that, if any portion of the line is broken in, a "pocket" is formed. The front line on either side of the gap stands firm, the communication trenches (which are

prepared for defence to either flank) sweep the interval between the firing line and the support trenches of the gap formed, and an organized counter-attack is launched almost immediately, assisted by strong bombing parties and by enfilade fire from machine guns and field artillery.

If the front line is heavily bombarded, the Germans are quick to evacuate the shelled area, moving either to their support trenches or to one of the flanks of the bombarded area. Generally, little attempt is made to answer the bombardment at the time, but a barrage is kept up behind our own front line to prevent any reinforcements moving up, and, when our own bombardment either ceases or lifts, the hostile barrage moves forward and plays on the interval between the German front line trenches and our own.

Taking the German front in France and Belgium as a whole, there are very few units available, either as army reserve, or as reserve for a group of armies, or as a central reserve to the whole front.

The Germans rely on obtaining the necessary troops to meet an attack by "milking" the other portions of their front which are not attacked. Their very carefully organized system of lateral railway communication enables them to get these troops to the threatened area often within 48, generally within 56, and almost invariably within 80 hours. If an attack promises to be dangerous the "milking" process is carried out by means of isolated resting battalions hurriedly moved up, not organized into higher formations. This was the case in Champagne and at Loos during September of last year.

Clearly reinforcements of this nature are of less fighting value than organized units, and it takes some time after the cessation of the attack for the line to be straightened out again and units to join their own formations.

When our attack finally does break through the German line, unless the Germans alter this principle, chaos must inevitably ensue in the German Army in the course of a very few days.

GERMAN SYSTEM OF ATTACK.[1]

6. On the Western front there has been no experience of German attacks on any large scale for the last six months.

Based on the analogy of the German operations in Russia and

[1]This was written before the German offensive at Verdun, a short description of which, illustrating the latest German methods of attack, is given in the Addendum at the end of this article.

in Servia the German system would appear to be, first, a bombardment extending over two or three days and culminating in an intensive bombardment of several hours' duration. This will be followed either by a gas attack or by an infantry assault without gas.

The infantry assault, so far as can be judged, is made with little skill, but in dense masses and with great determination.

Unless the bombardment and gas attack have been sufficiently effective to cause the hostile front line trenches to be evacuated, the repulse of the infantry attack should present small difficulty.

While the Germans are experts in bombing and in machine gun tactics, they invariably show themselves inferior to any of the nations against whom they are fighting when it becomes a matter of "cold steel."

ARTILLERY.

7. As in our own Army, the German artillery is divided into corps artillery, divisional artillery, and artillery for counter-battery work.

The normal German battery is now four guns, though it consisted of six guns before the war. These are often split up, working either singly or in pairs.

The gun positions are very difficult to detect. The Germans are adepts both in concealing the guns and in the use of dummy emplacements and other ruses to draw our fire in the wrong direction.

The actual gun in action is either protected from observation by overhead cover or is put in the open without any attempt at protection. German officers have claimed that by this means the gun is much less visible than if in a gun pit.

The Germans are very fond of using enfilade fire, and always endeavor to place their guns in such a way as to bring the maximum amount of cross-fire to bear on a hostile position.

Captured documents have shown that the Germans during the second half of 1915 had to restrict very considerably the amount of ammunition available. The system of supply appears to be a certain fixed proportion of shell either for each week or for each day to corps or to batteries, together with a reserve at the disposal of the army. Recently the army reserve has had to be reduced. Not only has the amount of ammunition thus decreased, but there has been a noticeable increase in the proportion of "blinds."

The best method of detecting German positions accurately is by cross observation on the flashes with accurate instruments, or of direct observation of flashes from aeroplanes.

Sometimes gun positions can be identified on aeroplane photographs, chiefly through the tracks leading up to them. It is doubtful whether the battery itself is ever visible in the photograph.

If a battery comes under our fire the Germans are quick to stop fire, withdrawing the personnel.

All accounts agree that the losses in the German artillery as regards men have been very low.

MACHINE GUNS.

8. The number of machine guns in the German Army at the commencement of the war was in the same proportion as in our own, viz., a machine gun company of six guns per regiment, *i. e.*, two per battalion. This number has been steadily increased, and the normal number now is from 12 to 15 per regiment.

The full number of machine guns of the whole regiment is generally left with units in the front line, consequently the proportion to length in the front line is exceedingly high.

The personnel is highly trained, and the guns are employed in a most determined manner.

Alternative emplacements are almost always provided.

During a bombardment it is customary for the machine guns to be removed to a dug-out close at hand and brought back into their emplacements only when the artillery fire lifts.

Emplacements are almost always to be found in salients, and bring flanking fire on the intervals. Many emplacements are made with concrete.

The German machine gun is particularly mobile and readily placed in position. Consequently, if a section of the front line trenches is evacuated, the machine guns are at once taken back to the second line or to the communication trench, or to one or other flank so as to deal with the attackers in the "pocket" mentioned in paragraph 5.

"MINENWERFER."

9. The position of Minenwerfer is generally either between the front line and supports or in the support trenches. There are invariably alternative emplacements. The ammunition is stored at some little distance from the weapon.

Dummy emplacements are largely employed.

A Minenwerfer ceases fire and is presumably removed immediately the Germans suspect that it has been located, either on account of our fire being directed in its neighborhood or if aeroplanes are active above it.

Three kinds are used: light, medium and heavy. Fire with the latter should at once meet with severe retaliation.

HAND GRENADES. RIFLE GRENADES.

10 (*a*) Bombing was introduced into the present war by the Germans, and both in their recruit depots and when the men are at rest they are constantly trained and exercised in bombing. The ideal aimed at by the Germans is that every infantry soldier should be a trained bomber.

A large supply of hand grenades is kept in the front line trenches, apparently at about every 15 to 20 yards of front, also in the support trenches.

In a bombing attack the usual organization is generally a few bombers at the head of the attack, often three men, two in the rear throwing over the heads of those in front. The supply is from hand to hand by a chain of men from the rear to the front. The German hand grenade usually has an attachment enabling it to be hung on to the man's belt. The bombers never carry their rifles.

They are protected by machine gun fire on their flanks.

Captured documents show that the Germans, like ourselves, used to suffer from a very large variety of types of bomb. The one in most general use now is a bomb with a long handle. The fuse is ignited by a type of friction tube, actuated by pulling a string in the handle. The fuse burns for five or seven seconds, the former being the most recent pattern.

Recently, the Germans appear to have been using a certain number of lachrymator bombs. The effect of these is very local and few cases of any injury being done to our men have been found.

So far no case has been found of a bomb with asphyxiating gas dangerous to life.

(*b*) The Germans make considerable use of rifle grenades, which have in certain sectors caused much annoyance. The most effective method of retaliation is by paying the enemy in their own coin, *i. e.*, by a heavy fire of rifle grenades at the hostile trenches.

SNIPERS.

11. The sniping art developed late in the course of the present

campaign amongst the Germans, and even at present they do not excel at it.

It is reported that recently a special rifle for sniping has been issued with telescopic sights and with no wood round the fore-end, so that it can fire through a small loophole.

Generally the German sniper works alone, without an observer. The favorite position for snipers is in the trees in the summer and in the ruins of a house during the winter. There appear to be few in the front line trenches.

RIFLE BATTERIES.

12. Captured documents have indicated that the Germans use rifle batteries to fire on roads used by our troops at night. The actual effect of these has rarely been great, though inconvenience and casualties are caused occasionally.

TELEPHONES.

13. The telephone is practically the only means of communication used by the Germans at or near the front line. Their wires are generally buried, or run along the sides of the communication trenches. Forward artillery observers are invariably connected, not only to their own artillery superiors, but also to the infantry H. Q. in the vicinity.

Frequent references in German documents have been found to a system adopted by the Germans for tapping our messages, either by induction or by earth currents. We have no information as to what results have been obtained except the negative information that often we have found the Germans greatly wrong in their estimate both of the number and the unit of our troops on their front.

With a view to preventing our signal service from tapping the German lines they have made all their currents in the vicinity of the front line metallic, *i. e.*, there is no "earth" anywhere near the front line of trenches.

The telephone system can often be identified in aeroplane photographs by the trenches made for the wires.

LIGHT RAILWAYS.

14. The Germans make very great use of trolley lines and light railways for bringing up their supplies to the vicinity of the front line. In general, all these lines have now been identified.

In the vicinity of the front line the trolley lines often run in trenches. Further back they generally follow the roads.

PATROLLING.

15. Systematic patrolling does not appear to be undertaken by the Germans to as great an extent as by our troops.

German patrols are generally weak and, except for the express purpose of waylaying our patrols, are usually unarmed or armed only with a revolver or bombs. Patrolling is almost always done by volunteers. Single man patrols are often used.

Sometimes, however, strong patrols are employed, strength 15-25 men, whilst patrols 50 strong have occasionally been encountered.

MINING.

16. Generally speaking the German mining, as far as the 1st Army front is concerned, has been defensive.

In a section where we undertake mining operations the Germans run out a series of shafts to a distance of about 50-60 feet beyond their parapet. These shafts are then connected by a lateral gallery and from this gallery short listening shafts are shot out to the front. Such defensive mining as is undertaken by the Germans appears to be usually only at a place where our miners have been heard in these listening posts at work. It is very rare for a German mine to reach under our parapet.

South of the La Bassée Canal, near Cuinchy and opposite the Loos salient, the Germans have showed great mining activity, and much of their work has been offensive.

PERSONNEL.

17. The German losses now considerably exceed one-fourth of the total military manhood of the nation. This is necessarily causing a great deterioration both in the physique and in the fighting qualities of German soldier as he is now met with. Yet, even now, he is stubborn in defence until threatened by cold steel, and in the attack he advances in dense masses with an apparent disregard of danger.

Individual initiative is rarely found. The German N. C. O. is perhaps the best example of German military education. It is the German N. C. O. who is generally left in actual command in the front line trenches and leads the attack. The officer, probably under orders from the higher authorities, usually keeps in a position of comparative safety.

Company commanders are generally either in the support

trenches, battalion commanders in dug-outs or houses 1,000 to 2,000 yards in rear. Senior officers seldom visit the trenches.

SUPPLY SYSTEM.

18. The Germans have developed to their utmost their railway system for the purpose of supplies. Their railway trains move much closer up to the front line than do ours. From the railhead of the broad gauge, stores are transferred direct to light railways and the trolley lines mentioned above. M. T. is now very little used for supply purposes, and there is little traffic on the roads behind the German line.

RATIONS AND FOOD.

19. There are various cases of deterioration in the food now issued to the German soldier.

The ordinary ration issued provides for—

Breakfast: Black bread and coffee;

Dinner: Black bread with thick soup, containing meat and lumps of fat with coffee or water;

Evening meal: Stew, with black bread and coffee or water.

Cookers come up in the evening.

A tobacco ration is issued, but no bacon, cheese (except in lieu of meat), butter or jam. All extras have to be bought out of the soldier's pay, which amounts to only from ten to fifteen shillings a month.

ASPHYXIATING GAS.

20. So far the Germans have only made use of one type of asphyxiating gas on our front, viz., chlorine. On the Russian front another type has been used, but recent reliable information shows that these two types—against both of which we have ample and complete protection—have so far marked the limit of German effort in chemical warfare.

ESPIONAGE.

21. So far as can be ascertained German espionage has so far only been effective in neutral countries and in the large towns of the belligerent countries.

In the zone of operations they do not appear to have met with much success.

At the same time it is known that the German system of

espionage is highly developed, and it is probable that constant efforts are being made to get agents close up to the armies in the field.

HEADQUARTERS, 1ST ARMY.

1st March, 1916.

ADDENDUM.

THE GERMAN OFFENSIVE AT VERDUN, 21ST-29TH FEBRUARY, 1916.

(*a*) During the winter, the sector of attack, *i. e.,* 34,000 yards, had been held by one German corps, consisting of 25 battalions. Several days before the attack this corps was withdrawn from the front line and relieved by four other corps, total strength 75 battalions.

(*b*) On February 21st the Germans opened an intense bombardment on the front of two of their Army Corps, from the Bois des Caures to Maucourt, *i. e.,* about 12,500 yards.

During the night of the 21st-22nd these two corps sent forward strong patrols (each of 2 officers and 50 men) to discover the result of the bombardment.

(*c*) On February 22nd the attack developed on the front from the Meuse to Herbebois inclusive, *i. e.,* on a front of 13,000 yards.

The assault was preceded by a very intense but comparatively short bombardment on the entire sector of attack; the area subjected to the bombardment had a depth of 1,000 yards.

Strong reconnoitering patrols were again pushed forward to ascertain the results of the bombardment.

The assault, in which two corps took part, was carried out by successive waves, which followed each other at 80-100 yards' distance. Some regiments were echeloned in depth by battalions, the leading battalion being in two lines.

Each unit had a definitely assigned objective, beyond which it was not to advance; further advance was to be carried out by the troops in reserve. The infantry was ordered not to persist in efforts to overcome any resistance which had not been broken down by artillery fire. Each unit was to await artillery support before continuing the attack.

The guiding principle appears to have been to obtain the maximum artillery effect with the minimum of loss to the infantry.

.1.

SKE
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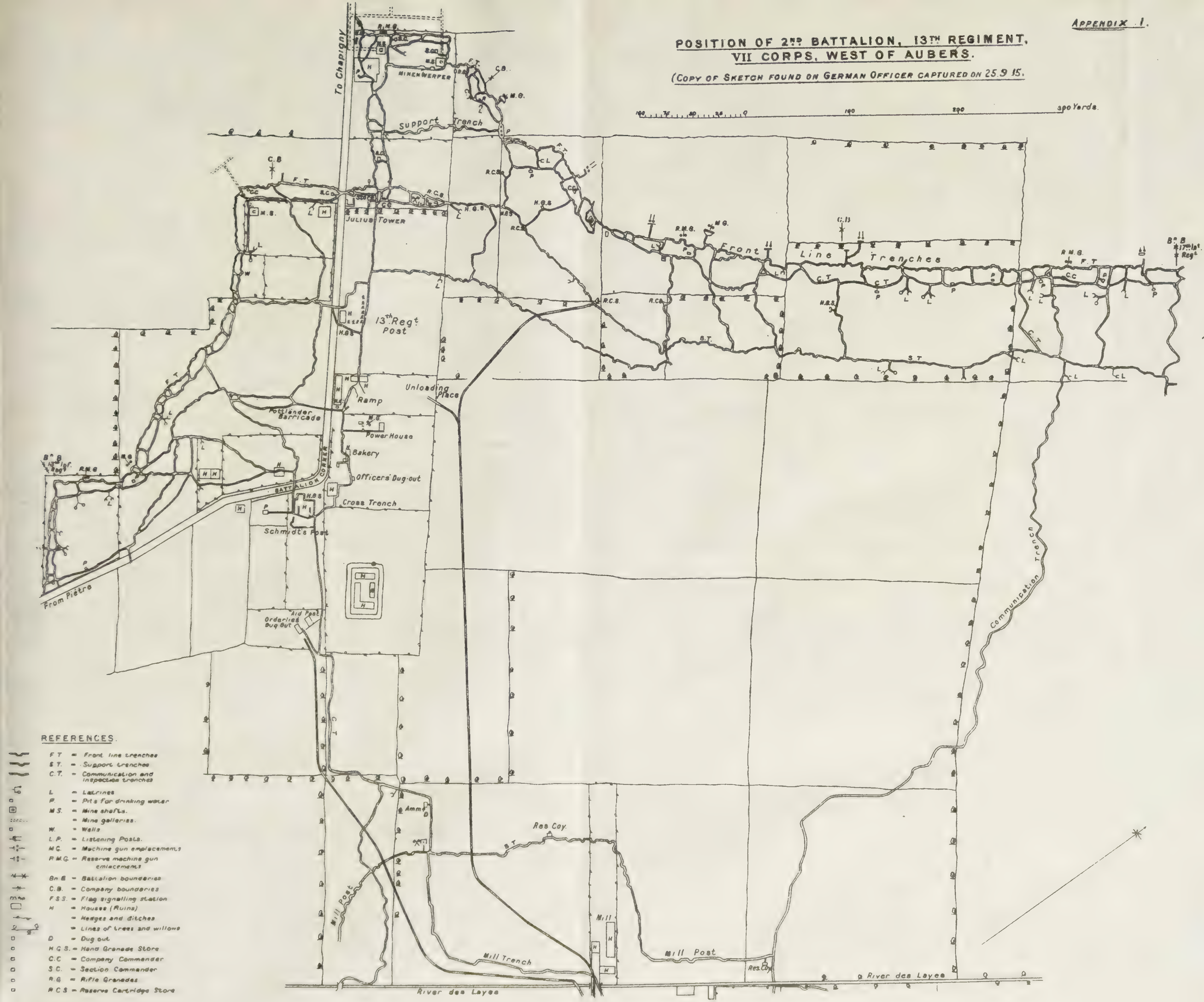
NOR

(Copy
German

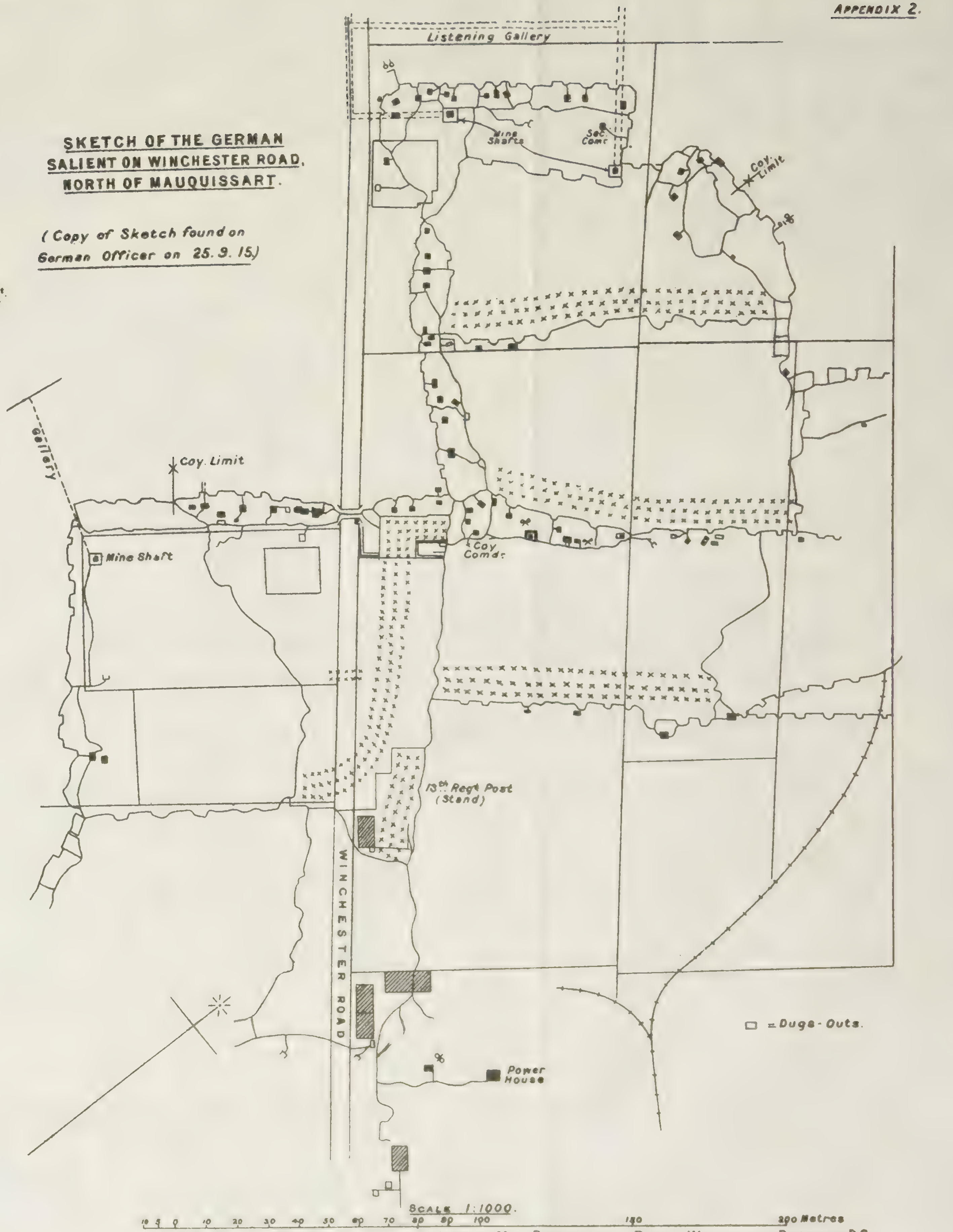
POSITION OF 2ND BATTALION, 13TH REGIMENT, VII CORPS, WEST OF AUBERS.

(COPY OF SKETCH FOUND ON GERMAN OFFICER CAPTURED ON 25.9.15.)



SKETCH OF THE GERMAN SALIENT ON WINCHESTER ROAD, NORTH OF MAUQUISSART.

(Copy of Sketch found on German Officer on 25.9.15.)



CENTRAL MAP REPRODUCTION PLANT, WASHINGTON BARRACKS, D.C.

Each corps had both its divisions in line side by side, each division with two regiments in front and one in reserve.

(*d*) These attacks differed notably from the methods previously adopted by the Germans, and outlined in paragraph 6. Little time was devoted to the registration of the heavy artillery, and the bombardment was comparatively short, but of the greatest intensity.

In general, the German methods in the matter of bombardment may be said to have resembled the system adopted by us a year ago in the attack on Neuve Chapelle, rather than anything that has been done since that time.

No special preparations had been made in the way of pushing out saps or advanced trenches; the German infantry advanced to the attack from their front trenches, which were in some cases 500-600 yards from the French lines.

The co-operation between infantry and artillery seems to have been close and effective throughout.

HEADQUARTERS, 1ST ARMY.
7th March, 1916.

[An account of German Methods of Trench Warfare, up to December, 1916, is to appear in the November-December number of MEMOIRS.—ED.]

A Visit to the English Front in France.[1]

BY

Capt. D. VICTORIANO CASAJUS.

(Continued from No. 46, July-August, 1917.)

THE SAPPERS.

These have their field of activity within the danger zone. During the night they put in shape the positions captured by the infantry, repair the trenches, set barbed-wire entanglements, construct shelters, run trenches of communication across the neutral zone that was, so as to connect the new positions with ramifications of the old, and above all, they make a way for conveying back the wounded who have fallen in capturing the enemy's trenches.

And, while the guns of the opposing side pour in their destructive fire, endeavoring in every way to frustrate the operations of this corps, the sapper keeps right on, compelled to face and share the common danger.

In addition to these duties, since siege operations, using the term in broadest signification, can not be carried on without the cooperation of the mine, he has to construct these also to help along the offensive, especially when, on account of the close proximity of the enemy's lines, the artillery can no longer assist in the work of destruction.

On the front, where the pits made by the projectiles of the heavy guns are so numerous as we have mentioned in another place, the sapper is often found engaged in running galleries betwixt these cavities and the water line beneath, hampered naturally by every kind of difficulty, where sometimes he is obliged to make the tunnel so low that it is scarcely possible for him to work on his knees. In other days, it would have seemed to be incredible that artillery fire could interfere with the construction of a sap; but in these days of invention and novelties everything is changed.

When the gallery of the mine has been carried under the parapet of the enemy's trench it sends out arms to the right and left forming a "T," so as to give room for a more wide-spread devastation when the blast is set off.

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[1]Translated from "*La Guerra y su Preparacion,*" *Estado Mayor Central, Ano 1 Numero 8,* Madrid. December, 1916. Translated by Maj. Henry Swift, Chaplain, U. S. A., retired.

At these depths, they often come across the bodies of the slain who have been buried beneath the parapet, while they are able to hear distinctly the footsteps of the men who are passing back and forth in the trench above.

The effects of the explosion of one of these mines in this twentieth century may well be imagined, as we reflect on the enormous strides that have been made in the science of chemistry. Their havoc is tremendous as compared with that caused by the "fire-mines" or the systems of "undermining" which were the methods in mediæval times, or even as compared with those of the modern mine, as first employed by Pedro Navarro in the year 1503 in the siege of "Castello del Uovo," near Naples.

The condition of the crater made by the explosion may be judged of from Fig. 10. And as to the scene that the ground in the vicinity presents, it is one of complete chaos, with splintered beams and boards, with earth sacks hurled about, while not a vestige of the trenches as they were before can be recognized. Everywhere there are fragments of bodies torn to pieces, of blood-stained uniforms and garments, helmets, rifles twisted out of shape, haversacks, bayonets, canteens, and all kinds of equipment. Then there are the wounded, with masses of flesh torn away, with limbs destroyed, the dead and wounded with clothing ablaze, hands, feet scattered about, etc.; and all this without speaking of those who are buried under the avalanche of earth and detritus that follows the blast.

Such is the scene of desolation and death, of ruin and destruction, which are commonly announced in the official bulletins after some such laconic fashion as this: "Yesterday a mine was fired under a portion of the enemy's intrenchments in sector X."

SERVICE OF COMMUNICATION.

The duties of the service of communication are more pacific; nor do their labors, although they penetrate to the utmost limits, have such ghastly outcome as those just described.

In fact, to the troops of the Engineer Department are entrusted the opening of new avenues of communication in the advanced zone to facilitate the operations of the first line, with all the immense traffic they involve, the laying down of numerous emergency tracks under the Decauville system, these being utilized for the transportation of building material used in the construction of the trenches, and of projectiles to the depots contiguous to the pieces themselves.

They have in charge, furthermore, the repair and keeping up of the roads and highways which form a network of intercommunication between the front and the bases; for it must not be forgotten that these operations are being carried on in what—in peace time—was the most thickly populated section of France. You may almost always find gangs of laborers, with trucks loaded with gravel, filling up the pits made by the bursting of the enemy's shells, a thing occurring daily, that they may put every obstacle in the way of the traffic of the other side. The extent of these operations may be

Fig. 10. Effects of the Explosion of a Mine.

judged of, when we consider that the number of freight trucks alone, used by the English, reaches the figure of some 30,000, as we have already had occasion to note.

To these troops is also committed the construction and care of all the labyrinth of communications along the line of trenches and back to the bases, covering approximately about 9,000 kilometers of territory (km. square).

And, again, all the transportation from railway terminals, which is immense, is under the charge of the engineers; and it is under their direction that the service of aviation has been inaugurated and kept up.

AVIATION.

Out of the experience gained in peace-time maneuvers, and partly from pure theory, various embryonic schemes and organizations of air service were devised, out of which have developed the systems in operation in the present war. It is not to be wondered at that the reality of conditions as they exist should have modified many of the original principles as maintained, and have introduced new ideas.

To-day it may be asserted that the things that are required in this fifth arm are being thoroughly tested and understood, and it may be confidently affirmed that in treating of a service that has developed under the inspiration of actual warfare, the conclusions arrived at are excellent, and have everything to recommend them.

Upon the substructure of the reconnoitering aeroplane, which was the first idea as to the military utility and application to be made of the conquest of the air, there has been erected and elaborated the entire system as it at present stands. Its principal employment at the first was to penetrate the enemy's territory in order to gain some knowledge of his plans, and to shape one's own accordingly.

But this invasion, which was so manifestly injurious to the enemy, imposed upon him the necessity of hiding or masking his artillery, thus giving occasion as a logical sequence to the creation of the aeroplane of observation, so that that arm [artillery] could ascertain the effects of its own fire; and this further suggested the thought of taking advantage of these incursions, and dropping bombs upon the objectives they might discover; thus leading up to machines for bombardment.

But as the work of observation, if it is to be done with any degree of efficiency, requires an absolute abstraction on the part of the officer from everything that does not lie in the line of his duty, there has come to be felt the necessity of having other machines to serve as an escort, and to protect him from any attack of those taking advantage of his indifference or unconsciousness of what is going on about him; and so there has come into being the "chaser" or fighting aeroplane.

We have accordingly now a reasonable classification, which the emergencies and demands of war in the air have come to establish, based on the various uses to which they are to be put.

These are: *Reconnoitering* aeroplanes; *observation* machines to note the effect of artillery fire; *bomb droppers* for the offensive; aeroplanes of *combat,* or "*chasers,*" according to the phases of fighting required.

Let us examine in more detail the mission of each of these, learning from that their peculiar characteristics, omitting, however, technical details, which have no place in this present article.

RECONNOITERING AEROPLANES.

These machines, on invading the enemy's territory, endeavor to procure for their command all information of interest that they can gather. They take photographs both panoramic and oblique, as these are denominated by the English, of the hostile zone (see Fig. 11), which, besides illustrating the maps used by the troops, are complementary to them, enabling the command to know the character and location of the defences constructed by the enemy.

They hover over the enemy's trenches, accumulating details as to their number and arrangement, and they watch, during the course of an assault, the movements of troops, so as to send warning to the proper point where the hardest blow is to be struck. During one single day we have seen on the Somme, on the eve of an attack, 22 English aeroplanes flying over the German lines along a stretch of not more than 11 kilometers.

As a natural result of the duties accomplished by these machines, the reliefs, which are on their way to the advanced lines, are often compelled to halt and wait for darkness before venturing to enter the belt swept by artillery fire, not only to avoid the danger that threatens them, but also lest they should reveal the particular sector for which they are bound.

As to the characteristic features of this class of aeroplanes; inasmuch as they are frequently exposed to the fire of the antiaerial artillery of the enemy and to attacks from their chasers, their very first requisite is facility in maneuvering, that they may avoid their fire; and ability to soar to great heights, or to sink rapidly to the earth, in order to escape from their attacks.

They have to carry, furthermore, a photographic outfit of special construction for the character of work required, a rapid-fire gun, and a wireless apparatus.

AEROPLANES OF OBSERVATION.

Their functions have already been treated of in our section on artillery. It remains, therefore, for us only to state the characteristic features of this class of air-craft.

The ideal apparatus would be of the "kite" (*cometa*) type, which could rise or descend at will, or could remain immovable over the point of view selected. But as, in the present state of aviation, such conditions do not seem to be practicable, the next best thing is to have it so arranged that it can fly slowly, thus permitting the officer to make his observations in every direction, and

again that it should be capable of escaping easily from the fire of antiaerial artillery, and from the attacks of aerial cruisers or chasers. It has also to carry a wireless apparatus.

In a word, the main essentials are that the machine should be light in weight, of small size, capable of ascending or descending rapidly, and able to carry one passenger—the observer—and flying in all kinds of winds.

AEROPLANES FOR BOMBARDMENT.

These generally work in groups, forming fleets of varying strength, which invade hostile territory in order to strike their lines of communication, depots, supply trains, and even columns of troops on the march. On one occasion, a group composed of 68 machines of this class combined in a raid. Since the inception of the use of these destructive machines, the other side has resorted to spreading branches of trees over the supplies and ammunition carried on the platform cars to the trains.

In certain instances they have used these craft to support attacks by the infantry, throwing the rear of the enemy into confusion, and hindering them from sending forward supports and supplies, especially food, giving them no rest by day or by night.

Airships of this class constitute the "*dreadnaughts*" of these new instruments of war. Their dimensions, however, have their limitations; for there must come a point where their availability for the offensive would be in inverse proportion as their size increased. It is considered better to distribute the same weight in bombs and armament among a considerable number of machines, thus attaining greater safety in their manipulation, increasing the precision and rapidity with which they can launch their missiles, and above all facilitating their escape when flight becomes necessary.

Their principal characteristics, then, would be a minimum velocity, motors of great power, a very considerable radius of activity, facility in maneuvering so that they may easily evade the fire of artillery, and, while they have comparatively little to fear from chasers, to be accompanied by machines of that class, whose business would be to deal with those of the enemy; but even with such an auxiliary it would be well to be provided with machine guns.

According to report, the French craft of this class are mostly triplanes, having a carrying capacity of six men, and being provided with a mechanism which supplies the bombs to the man whose business it is to drop them.

FIGHTING AEROPLANES.

These are the latest development of military aviation, the use of which has already been touched upon. For service of this kind the machines must be of light weight, so that they can rise with ease to a great height and hover over their adversaries, a detail that is of supreme importance in aerial warfare. This militates against

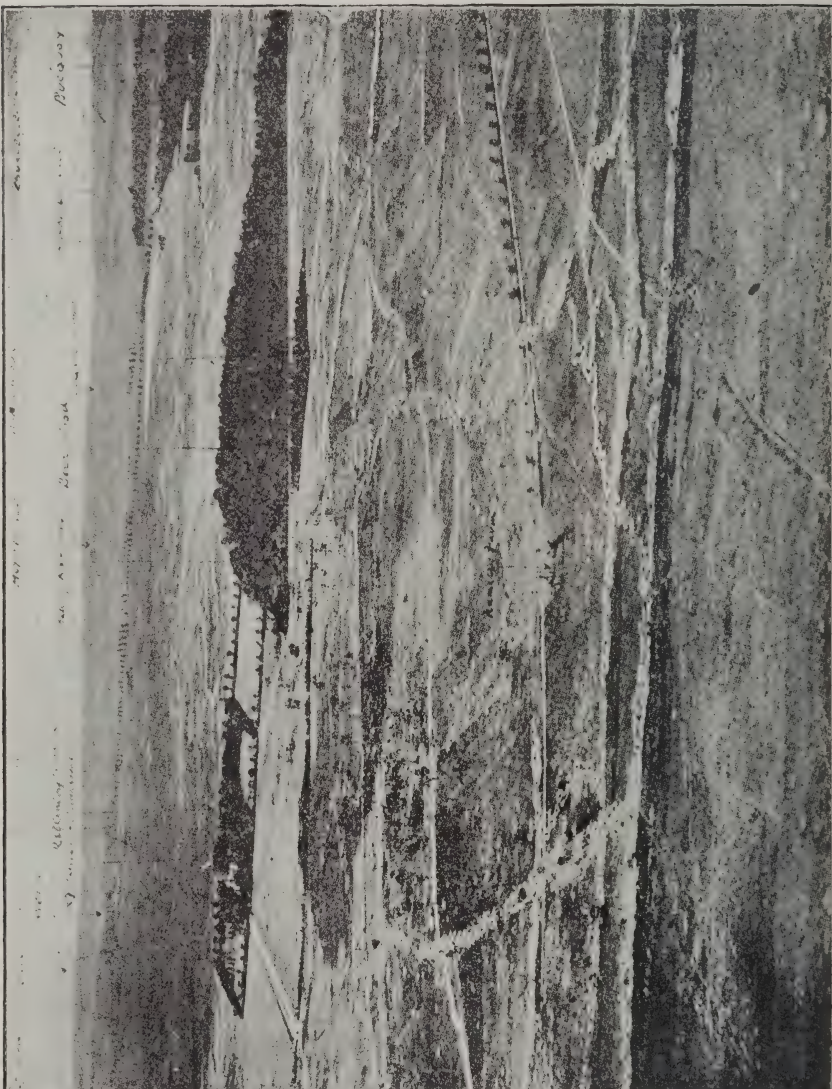


Fig. 11.

their being of any considerable size, and in consequence naturally affects the weight of their armament and the caliber of their pieces.

These are the only machines that are provided with a single seat.

. . . .

The pilot has, in addition to the duties of that position, to serve the piece he carries. Experts are figuring on the construction of a machine with two seats.

Before the war, and even after its commencement, there were two theories diametrically opposed as to the placing of the propeller. There were those who advocated its location in front, while others maintained that it should be in the stern. The first method gave greater velocity, but interfered with the aim and handling of the weapon employed. This disadvantage did not exist under the second method, but it detracted from the speed. At length the first triumphed; for it was considered easier to improve the arrangements for firing than to sacrifice, on account of any difficulties in that direction, its increased velocity, which in fine is the factor that contributes best to the purpose for which it was designed, namely, attack.

The necessity, then, being demonstrated of employing different varieties of machines, it is easy to comprehend how impossible it is to unify the models, as was proposed in the early days of aviation. For, while the ideal in observation aeroplanes, for example, is that of perfect immobility over the points to be surveyed, the fighting aeroplane requires on the other hand the greatest possibility of speed. That is to say, antagonistic conditions may not be combined in the same machine. And so, as was remarked in the beginning of this article, experience, taught by errors and mistakes of the past, has discarded some of the principles which were regarded as indubitable in the infancy of aviation.

AVIATION PARKS.

All of these machines are kept in grounds especially arranged for the purpose, situated at various convenient points in the rear of the advanced lines, and at variable distances, wherever the ground is most suitable and available. Some of these are as much as 30 kilometers back of the lines, as it is considered that in air navigation the distances are vastly diminished by the ability of the machines to cover them in a brief period of time.

ANTIAERIAL ARTILLERY.

With peril threatening from the air, the antiaerial gun naturally came into being, and with it the creation of mobile units of artillery of this class. The guns are mounted on automobiles, and these are provided with means for taking observations, and with ammunition adapted for the special purpose of fighting aircraft.

These units pass from place to place, and frequently follow the

Fig. 12.

aeroplanes in their flight with the purpose of destroying them. We can make no report as to their characteristic features, as we have had no opportunity to examine them.

RÉSUMÉ.

As a résumé of all that has been given on the subject of aviation, it may be affirmed that the Fifth Arm is the most striking illustration of the revolution which the gasoline motor has effected in the art of war.

In effect, the aeroplane detains the infantry in its advance, compelling it to move during the night, it observes their positions and movements, while it cooperates with its own forces when an assault is attempted. It compels the artillery of the enemy to secrete itself, while, by its observations at the same time, it directs the fire of its

Fig. 13. Shelter for the Staff of an Infantry Battalion.

own artillery. It menaces the labors of the engineers, and demolishes his works by bombardment. It embarrasses the services in the rear. It cuts off the command from the firing line, as will be shown in the next section following. And, finally, it disputes the dominion of the air with the machines of the other side. As may be realized, it propounds an abundance of problems to the armies of the future.

DISTRIBUTION OF A COMMAND.

The extensive range of modern artillery, the aeroplanes, the great forces of nature appropriated to the service of man, and the perfection attained in the means of communication, have resulted in a wider separation than used to be between the headquarters of a command and the lines where the conflict is actually raging.

Only the chiefs of battalions live in the trenches (see Fig. 13).

The headquarters of the higher units are distributed from front to rear to a depth of some 70 kilometers distance from the firing line. (See Fig. 14.)

The distances of these from each other depend naturally on the character of the country, and the conditions of the struggle as it develops. But, as a rule, we may say that brigade headquarters lie about 3 kilometers back of the trenches, generally in towns or villages within reach of artillery fire, and consequently in ruins; the general and staff occupying cellars or living in shelters well covered with earth.

Those of the division are farther to the rear, in inhabited places, and about 8 kilometers from the lines, being out of the range of medium-sized guns.

Those of the army corps are in cities of some importance, which are generally nuclei of communication, lying about 15 kilometers to the rear, and only liable to aerial bombardment if their location is discovered.

The headquarters of the commander-in-chief of an army are about 70 kilometers away from the firing line, and completely out of the danger zone of artillery. They are established in buildings appropriate for the purpose in some city of first importance.

All of these are connected together by channels of communication, which at any moment assure the passing of an order to the most remote and obscure section of the lines, which all depend on the central authority, receiving their instructions through the intermediate grades; and thus they are carried eventually to the commanders and captains in the trenches themselves.

The subordinate headquarters are required to apprise of the course of events, not only their immediate superiors, but also the headquarters that are adjacent to them on each side; so that all may be kept posted in regard to any important change occurring in the situation.

The character of the agencies of communication varies with the degree of security offered by the section in which they are installed. Thus the telegraph and telephone lines which connect the general commanding with the corps headquarters are like the ordinary ones used in times of peace. Between corps and division headquarters they may be set on poles ordinarily, inasmuch as the danger of injury by bombardment is of infrequent occurrence; but from the division headquarters forward they have to be underground, and at some considerable depth; else they may find their communications cut off on account of the wires having been severed by the enemy's shells, as has occurred several times between brigade headquarters and the advanced lines, where the effects of the artillery fire are more frequently experienced.

Communication between contiguous headquarters is kept up by such means as are practicable or available: by automobiles, by motorcycles, by the ordinary wheel, and even by mounted orderlies and messengers.

Independently of all these, the general in command, and some-

times some of the subordinate commands, avail themselves of the "wireless," especially in communicating with aircraft, or with war vessels, when occasion demands.

At some of the headquarters are sometimes to be found parks of large drays for the transportation of troops, so that they may be carried rapidly to points where the need of them is urgent.

In all of the headquarters, particularly in those of higher grade, there are maps on a large scale of the zone of operations, upon which are indicated the positions and movements of troops as they daily occur, tiny flags of various colors being used to represent the units in the various sectors of the front.

The stationary character of this war has served to facilitate to a great degree the complicated functions of command, where the changes that are constantly occurring can be accurately noted, by a system of communications which are but little affected by the vastness of the field embraced.

All this contributes to the separating of the commander far from the dangers, which in other times were wont to beset him, increasing in a like proportion his responsibilities, as his sphere becomes more complicated and extended. That is to say, the further the general is removed from the line of fire, the more important do his duties become. Such are the changes that are to be recognized in the art of war. Personal valor has come to be relegated to a secondary place and to be outranked by a higher and much more necessary quality—that of capacity.

SERVICE OF ADMINISTRATION.

The ease of communication that exists in the zone occupied by the English, the normal conditions of traffic which the stationary character of the conflict makes possible, and the revolution caused by the introduction of mechanical tractors for purposes of transportation, have enabled the services of the rear to be carried on with a regularity and despatch which the experience of no former war anywhere presents.

The automobile truck, being substituted for animal traction, has radically transformed and improved the whole administration. Thanks to it, they can purvey the needs of the effectives on the English front to-day with a saving of some 17,000 vehicles[1] as compared with the number required when animals were employed. And in addition to this, there are not needed so many relay depots as were formerly required, in order to facilitate the daily trip; while the greatest distance now between base and front is only about 120 kilometers. This comes to represent in the handling of matériel an amount of labor fifteen times less for the same number of effectives.

[1]These figures are, of course, only approximate; since for evident reasons we are restrained from giving too accurate concrete information as to the strength of the effective forces.

For this reason the English soldier is able to have a ration delivered every day of meat and fresh bread, and that he is looked after better than he ever was before. The daily ration during the Boer war, which consisted of a pound and a quarter of biscuit, a pound of fresh or canned meat, four ounces of marmalade, three of sugar, two of preserved vegetables, the third of an ounce of tea, half an ounce of coffee, salt and pepper, has been increased in this war by four ounces of bacon, three of cheese, while fresh beef is furnished every day, and a better ration of tea, besides the eighth of a can of condensed milk.

This is an increase that, without the aid of the mechanical tractor, would seriously have embarrassed the service of delivery; for, multiplying the items by the number of men supplied, the total foots up to some hundreds of tons.

These facilities of transportation have been considerably enhanced and supplemented by conditions peculiar to the part of the country where lies the theater of war. For it is well known that in the north of France the sluggishness of its water-courses and the comparatively slight dip of its watershed have caused, in the course of ages, the construction of a dense network of canals, which same are utilized as much as possible for transportation, boats especially constructed for the purpose in England being employed.

REPAIR SHOPS.

As there is so much wear and tear to equipments and mechanisms along the front, advantage is taken of the return trips of the trucks to send back to the bases everything that is capable of repair, so as to avoid the necessity of returning them to England, with all the delay and expense that such a measure would involve.

With this end in view the English have established repair shops at the bases visited by us, which have a contingent of some 5,000 operatives, men and women, where everything is repaired that comes from the front, save where the damage is too great for their handling. There we saw cannon, rapid-fire guns, rifles, vehicles of every kind, camp equipage, bicycles, pocket watches, goniometers and other instruments of precision, all undergoing repair; while there are also carpenter shops, tailoring and cobbling shops, etc. The shoe repair establishments seemed to be the most important of all, judging from the rush and the number engaged; for of the 5,000 employees 800 are devoted to this work alone. The shoes go through certain processes that are worth describing. When they arrive from the trenches they are shapeless masses of clay; and the first thing done is to submit them to a thorough scrubbing, which is done in a kind of trough by brushes furnished with metallic bristles, from which the shoes freed of their accretions emerge nicely cleansed. This work is always performed by women.

They are then inspected to see what repairs are needed; and if it is soleing or heeling, they are sorted out in baskets according to size, and a number of them of the same measure are run through a

P.M.B.—Battalion S Headquarters. C.G.G.—General in Chief's Headquarters.

FIG. 14

P.M.B.–Battalion Staff. A.C.–Field Artillery. A.G.–Heavy Artillery. C.G.B.–Brigade Headquarters. C.G.D.–Division Headquarters. C.G.C.–Corps Headquarters. C.G.G. General in Chief's Headquarters.

FIG. 14

machine, coming out—it is a matter of seconds—with the operation completed.

As the shoe has become all stiffened by the hydropathic treatment through which it has gone, the next step is to soften it, and this is done by submitting it to a bath of oil. From this it is subjected to a drying process, and then goes back to the front as it came, careful note being taken in the office of everything that passes through the shops. The number of pairs of shoes that are handled in a week amounts to some 22,000; an eloquent testimony to what life in the trenches must be.

COMMISSARY AND SUPPLY DEPOTS.

Service in the commissary department (and quartermaster—see last paragraph of this section) is performed with the most perfect regularity, thanks to order and system. The depot which we saw, over which a captain of the subsistence corps presided, ministers to an army of 350,000 men, and disposes of two ship-loads every week. It calculates to have on hand a month's reserve supply for that number of effectives.

The depot consists of three large sheds or receiving warehouses of equal capacity, situated right on the dock, which permits at once the discharging of the ship's cargo and its distribution into the proper compartments, mechanical devices being employed, which minimize the personnel required and facilitate the despatch of the work.

These three receiving depots lie parallel to each other, and are perpendicular to the wharf. In order to avoid confusion and errors the requisitions coming from the front are filled on the ground immediately, the goods being transferred to another immense storehouse in the immediate vicinity, which faces the three sheds, running their whole length including the spaces between them. This great store-house, in its turn, is in direct communication with the branch of the railway which connects with the regular stations. It has separate sections, where the various classes of goods are sorted out, each of a kind by itself.

The work is done with such expedition that at half-past ten in the morning, the hour of our visit, all of the business connected with the front was over, and there was not a sign of anything going on anywhere.

Adjacent to the docks are also great supply depots of clothing and equipments, from which the officers and men can obtain what they need without being obliged to send to the home country.

BAKERIES.

The bakery which we visited impressed us also with the sensation of vastness. It has 90 ovens and 800 bakers. It turns out 310,000 rations daily, all done by hand; and it holds a month's reserve of flour, whose value is about a million pounds sterling. The order and discipline maintained are the first things that strike

the visitor, as he thinks of the great number of men employed in this service.

As a résumé of all that we have narrated, it may be affirmed that the service of administration has wonderfully improved, in comparison with conditions as they prevailed in other wars. The bases, bringing the mother-country into closest touch with the front, and mechanical traction shortening the distances, are factors that have served to ameliorate greatly the conditions of life for the men in the trenches. And to this have contributed in no small degree the field kitchens, which, as much on the march as in permanent stations, supply the soldiers daily with at least one hot meal. We have seen great numbers of these everywhere. So it is to be seen that the well-known aphorisms, "The army moves on its belly," and "foot-wear makes infantry" have been well thought out and taken account of by the English, utilizing every instrumentality that modern progress has made available.

As to the future, it is easy to forecast the changes that the motor must effect in the science of logistics, greater even than the arts which minister to the comfort and efficiency of an army . . . have yet accomplished, some features of which we have noted.

SANITARY SERVICE.

Between the cannon, which compels those connected with the sanitary service to remove as far as possible from the danger zone, and the means of transportation, which facilitates the removal of the wounded, there has followed a great transformation, changes which, as far as the sanitary or medical department is concerned, have come to make war more humane, doubtless as a counterbalance against the ruthless slaughter effected by the artillery.

. . . .

REGIMENTAL FIRST-AID STATIONS.

These are out-posts of the service, stations which are located in the trenches themselves, either under shelter or in some spot comparatively shielded from the fire of the enemy.

The wounded are carried to these by the litter-bearers, and receive first aid, the package being used which every one carries sewed in the skirt of his blouse. The identification badge, which a soldier wears under his collar and an officer inside of his cuff, serves as a means for ascertaining the name, rank, and organization of the wounded.

ADVANCED STATIONS FOR TREATMENT.

As in the majority of cases the fire of the artillery has driven the division ambulance train out of its range, it has been found necessary to establish intermediate stations, where the wounded can be cared for while they are awaiting the arrival of transportation.

In general they are situated from 1 to 2 kilometers back of the trenches, and located in the basements or cellars of ruined houses,

with plenty of earth-sacks on the roof as a shield against the bombardment to which they are frequently subjected.

In these there are always two apartments or—at least—places partitioned off; one where wounded are brought and wait on their litters for their turn, the other is where the work is done. It is provided with a table brightly illuminated by an acetylene lamp; for even if there are doors and windows, these are covered over by earth-sacks. After having been bandaged at the first-aid station the wounded are carried by the litter-bearers to these advanced stations by way of the communicating trenches. The difficulties of this journey in the heat of action may well be imagined. Sometimes the two litter-bearers will be struck, and fall down beside the man they were carrying. Oftentimes they are compelled to defer the rescue of the wounded until after nightfall. During this period of waiting many of the wounded are struck again, sometimes killed. Such is, on its part, the bombardment as contrasted with and opposed to the other humanitarian labors.

When night comes, the wounded pour by dozens into these stations. Some stay only long enough for the doctors to see if the bandages are properly placed, which were applied at the first-aid station, and to inject some anti-tetanic preparation. Others, whose cases are more grave, are dressed anew, sometimes being operated on, or even amputations being performed, provided that the necessity is urgent.

All of this work is done by only two surgeons, a captain and a lieutenant, in many instances under artillery fire, with shells bursting around them, while the other wounded men on the litters await their turn.

FIELD DIVISION AMBULANCE CORPS.

If there were not some means of speedily clearing out these advanced stations, it would not be possible to accommodate the wounded, especially on the days that an attack is on. To accomplish this the automobile is used with great success, carrying the patients to the division field hospitals, which are located as a rule without the danger zone, as far back at most as the division headquarters.

These vehicles, so constructed that they can carry four men recumbent or eight men sitting, come up to the advanced stations whenever it is possible and, as the distance to be traversed is not very great, they are able to make a number of trips during the course of the day. I have heard of ambulances transporting more than 200 wounded during the course of a week, and in their first period of service; which means about 28 a day and 7 round trips. On one occasion a single ambulance carried back 144 wounded during the night; on another 235 were conveyed during the course of the 24 hours. Consider the time it would have taken to accomplish such a task without a machine; consider also the sufferings to which the wounded would otherwise have been subjected.

While it is true that the number of wounded in this war is ex-

cessive, the means employed for their relief are approximately abundant; for besides the ambulances proper they employ also the ammunition and commissary trucks which are to return empty, unless in the latter instance they have been used for the hauling of beef or of other unsavory and unsanitary matériel.

The wounded having arrived at the division field hospital, they are cared for and their wounds dressed anew with more tranquillity and better appliances; and they are then quartered usually in hospital tents, the patients to be returned, if the cases are light, in a few days to the front, or to be transferred in automobile ambulances to other field hospitals established in the rear, in store-houses and barracks of more substantial construction; or else they are sent to distributing railway stations, where they await the arrival of the hospital trains.

HOSPITAL TRAINS.

These trains are amply provided with means for the care of the wounded and sick; and in a few hours, after a comfortable ride, they leave them in permanent base hospitals. If conditions are satisfactory they also make use of the canals which abound in this region, availing themselves of such conveniences and matériel as are at hand and fit for the purpose. This kind of transportation is practically the most comfortable.

The allies have 30 hospital trains in the West. . . . The French trains are numbered from 1 to 11, inclusive. From 12 to 31 (exclusive of number 13, which does not exist) the trains are English.

Each train is composed of 14 units, with every convenience for the kind of service for which they have been designed, kitchens, operating coaches, dormitories for men, for officers, etc. Each train can transport about 400 patients. The maximum distance to be covered by any of these can be accomplished within 24 hours, the shortest in 8. The trains are all painted khaki color.

CONVALESCENT HOSPITALS.

At one of the bases visited by us there is a convalescent hospital, where men whose wounds are not so serious, and whose stay will be accordingly of brief duration, are cared for instead of being sent back to England, thus saving considerably in expense.

The dormitories are in hospital tents, while there are several more substantial structures for the messes, for canteens served by ladies—married and unmarried—who have volunteered for the purpose; there are recreation rooms, and shops for making tin-ware, shoes, coarse matting, etc., where the men can at once find occupation, and are able to kill time.

The characteristic features everywhere are scrupulous cleanliness and the excellent treatment of the patients. There are bathrooms, showers, and disinfecting plants, and the food is nourishing and abundant, as the appearance of the patients testifies. At the time of our visit there were flowers all about, and the hospital

looked more like some pleasure resort than what it really was. At that time there were some 1,800 cases, and up to the time of our visit more than 3,000 had been under treatment and discharged. The period of residence averages about two weeks, while some who were there then had been under treatment previously as many as three times.

HOSPITAL SHIPS.

In spite of all the means at their disposal on the continent for the excellent treatment of the wounded, there are oftentimes cases where it is necessary to transfer them to the home hospitals (in London, etc.), whose organization and administration have been treated of in the first number of "War and Preparation."

For this service the English have several hospital ships conveniently moored at the mouth of the "Canal de la Mancha" (not located by translator. S.), which is the best point of embarkation for the purpose.

The ship that we visited had accommodations for about 300 persons, with comfortable cots suspended in such a way as to counteract the effects of the ship's motion—rolling, pitching, etc.—there being also ample spaces between them, the cots being furthermore provided with cords pendant from the ceiling, by which the wounded are able to steady themselves when they need to change their positions.

The operation of embarking is accomplished by carrying the patients directly from the hospital trains, which have their termini at the docks where the vessels are tied up, and conveying them by means of cranes in hammocks or slings constructed especially for such service through a hatchway to the particular part of the ship where they are assigned. Comfort and cleanliness are the most striking features of the vessel, while places are provided for bathing, operating, disinfecting, etc.

HYGIENE OF THE TRENCHES.

The slight amount of sickness, up to this time, prevalent among the troops along the front, is one of the most amazing circumstances of this war; and it is because every precaution has been taken, with marvelous forethought, to prevent its invasion.

As to the troops on the advanced lines, we quote here some paragraphs from the instructions issued for the guidance of all in the trenches, instruction very much to the purpose:

> The importance of cleanliness, and the necessity for observing the rules of sanitation as far as it is practicable, cannot be too strongly insisted on. Back of the parapet of the communicating thoroughfare (*parapeta de gola*) there will open out in the shape of a "T" side trenches, where latrines will be installed.
>
> There will be placed there pails or cans of regulation size, which will be emptied as often as necessary, and the contents buried outside of the trenches.

The trenches must be kept at all times scrupulously clean; for which purpose all food scraps, emptied tins and garbage will be placed in receptacles provided for the purpose, which will be emptied during the night, the contents being buried.

The use of disinfectants should never be intermitted. The drains should be constantly treated with them; and all stagnant pools should be cleared out, and dried where it is possible.

In order to see that these regulations are strictly complied with, regulations which in one and another way affect every nook and cranny of the lines, a daily inspection is made under the direction of the medical corps in each of the sectors. It is only by such measures that, with such a vast agglomeration of men, epidemics have been restrained from breaking out, such as have almost always occurred, with all their fatal consequences, in the wars of other times.

From all that has been given it is to be seen, that while it is true that artillery and the like have made such havoc in the ranks, the businesslike and orderly manner in which affairs are administered in the rear, aided as they are by the motor, has contributed largely to ameliorate the condition of the sick and wounded in this war. For to cover a zone that at the most extends no more than a hundred kilometers back, and to reach the hospitals at the bases, they may count on means of transportation so rapid as the railways, which penetrating the field of operations are met by the motor ambulances; so that in a few hours the wounded are placed under normal conditions of care and attendance, a journey that would in past times have constituted a veritable Odyssey.

VETERINARY HOSPITALS.

The English have always been noted for the excellent care they take of their stock. With them the war is no exception to this rule. They have, in effect, a veterinary hospital in the rear for every sector, consisting of great shelters or stables constructed of frame and canvas, where animals are most sedulously cared for, as may be judged by the appearance of most of them.

Amongst the sicknesses or complaints most difficult to handle must be reckoned sarna and vermin (*piojo*, lice). These cases, after being properly isolated, are treated with hot disinfecting baths, the animals being compelled to swim in tanks constructed especially for the purpose, which are provided with runways at the ends for their entrance and exit, while their bodies are thoroughly scrubbed with specially designed brushes.

Each group of disorders, as well as of wounds, occupies a shelter separate from the others. And to further insure immunity from contagion every animal, on its entrance and before its departure from the hospital, goes through the malein test in order to ascertain the presence or absence of glanders.

CLOTHING AND EQUIPMENTS.

As a part of his equipment, the English soldier carries a shovel and a hatchet, while he has in addition 250 cartridges distributed in a belt, and in two sets of pouches hanging on the sides by a bandolier.

As rainstorms are so frequent in the region where these troops are serving, each individual is provided with a waterproof cape, khaki colored, which covers his body and the legs to the knees.

To relieve somewhat the burden which the weight of this equipment imposes, the Canadian troops have resorted to a new method for carrying the knapsack, suspending it from the head by a canvas strap, which bears the weight from beneath, thus relieving the pressure on the back and shoulders. The device is not æsthetic in appearance, but it serves its purpose.

The uniforms of generals and officers are eminently practical. There is a blouse of khaki cloth with turn-down collar, a shirt of the same with falling collar, a khaki cravat, breeches and cap. The devices are worn usually on the flap from the point of the shoulder to the neck, and are of blued steel. The half-boots are made of a single piece with Norway tops, and serve well to preserve the feet from damp.

The overcoat is of woolen stuff something like khaki, with skirts to the knees, and double-breasted; and the waterproof is of similar form and like color, with a large collar that may be raised to cover part of the face.

Along the entire front we have never seen an officer with a saber, everyone carrying the classic ''swagger-stick,'' which is found very handy in going over slippery places in the trenches. Not having any ourselves, we had at times to improvise them, cutting canes from the trees, as walking was at times almost impracticable without some such support.

POLICE IN THE CAMPS AND CANTONMENTS.

Order being the principal characteristic of an Englishman's existence, we find it extending to the utmost limits of the advance. Along the lines of the trenches there is an abundance of guides to lead the troops to the stations assigned them, while numerous posters are hung up to direct the enormous traffic that the various services involve.

In the cantonments, camps, and places of residence of the headquarters staff there is a police service as complete as may be found in the great cities of the mother-country. Thanks to it, perfect order reigns everywhere.

[NOTE: The aerial photographs (some of which are copied here) have been furnished by the General Staff of the English Army; while other sketches have been reproduced from the *Illustrated War News.*]

Entrenchments and Camouflage.

Lecture by a British Officer Skilled in Landscape Gardening.

GENERAL PRINCIPLES.

It would be a difficult matter to exaggerate the importance of trench-making in the present war, as for long stretches of time we are on the defensive; and even on the offensive—as we are on the Somme at the present moment. It is necessary not only to entrench on the flanks to prevent the lines of communication being cut off, but also to consolidate captured trenches. In spite of the fact that its importance is recognized, many striking possibilities have been overlooked. This is probably due to two causes; trench-making is nominally an engineer's job, but the infantry primarily site, construct and live in the trenches, the consequence being that they have been to a certain extent neglected by both.

It was a unanimously expressed opinion by the Germans and to a lesser extent by ourselves at the commencement of this war, that if the infantry paid too much attention to trenches, it would destroy their spirit of the offensive. We used precisely the same argument in regard to the use of cover previous to the Boer war.

Many years ago, shortly after the Jameson Raid, I remember hearing a discussion among some officers who were discussing the Boer method of fighting. They were almost unanimous in their opinion that the victory over Jameson was a fluke, and that on the next occasion when we were able to catch the Boers in the open we should not have the smallest difficulty in licking them. A civilian present suggested that if the Boers found it paid them to hide behind rocks, it would be somewhat foolish of them to come out. This suggestion gave rise to a considerable amount of indignation, and it was stated very forcibly that no man who called himself a soldier would ever dream of hiding behind a rock. The civilian remarked that he would not be a bit surprised if we found we had to learn to hide behind rocks before we managed to beat them.

We discovered during the Boer War that there was something wrong with our fundamental ideas of waging war, and even to-day there are points of view that have not been adequately considered. Success in war depends on inflicting a maximum amount of damage to the enemy with a minimum of loss to ourselves. The stoutest heart or the broadest chest will not stop a machine gun bullet.

It should be obvious that in these days of modern artillery, machine guns and magazine rifles, no troops in the presence of the enemy during daylight can possibly live in the open for more than a few seconds. Modern war must of necessity be a war of trenches up to the very end. An intelligent training in the construction of trenches is therefore of primary importance.

The first battle of Ypres should have impressed upon us the value of even hasty cover, and there can be little doubt that a man under cover and especially concealed cover, is equal to at least ten men in the open. There is much more glamor and glory about the offensive, but the defensive is of vital importance, and an interest in the defensive does not in any way destroy the spirit of the offensive, but has precisely the opposite effect. Those battalions who are constantly devising all kinds of traps, sniping ruses, etc., not only inflict more damage to the enemy but ultimately, by becoming top dog, have fewer casualties, and raise their morale to such an extent that they are able to undertake the offensive with much greater effect when the time comes for them to do so.

The evolution of the trench during this war has been an interesting study, and there are still very divergent opinions as to the value of varying types, so it is evident that no one can dogmatize in regard to any particular pattern.

There should be no *fixed pattern of fire trench.* If trenches are constructed on fixed patterns, according to the text-books, it would be just as reasonable to present the enemy with a plan of them, but there are some general principles which all trenches should conform to. There can be little doubt, the chief objects in view in making trenches are the following:

1st. Concealment, not only from the ground but from the air, and also concealment of the men's heads while firing over or through a parapet of a trench.
2nd. An extensive field of vision and fire.
3rd. A maximum amount of protection from rifle and the various types and kinds of shell fire and hand grenades.
4th. Efficient drainage.

5th. They should be designed to facilitate an attack, and should provide a maximum amount of fire control and firing room in the trenches.

6th. In the event of a possible retirement, a trench should be of such a kind that it is of little value to the enemy; in fact, it should be made into an actual trap for them.

7th. A maximum amount of comfort for the men, ease of communcation, removal of wounded, and efficient sanitary and cooking arrangements, etc.

8th. Rapidity and simplicity of construction.

We now proceed to examine these different points and discuss them. I shall be very grateful to you, if, after my lecture you will ask me any question on this subject that you think fit. What I have to say is not altogether according to the books, and anything that does not appear to be sound common sense I should like you to draw attention to at the close of my lecture, so that we should have the opportunity of discussing it.

We will now discuss these points seriatim.

CONCEALMENT.

It should hardly be necessary for me to point out the value of concealment, as it is obvious to any person of average intelligence that *so long as you remain concealed you are in no danger from the enemy except by chance shell fire.* But since the present war, many return from Flanders and state that concealment is no longer of any value owing to the fact that trenches are now-a-days so near together. They state that, in the present war, no one bothers about concealing their fire trenches; in fact, in most parts of the line, owing to the water, the men on both sides live behind great sand-bag breastworks, regular forts which one can see miles off, with little houses and kitchens and the kitchen fire-smoke curling up in the most brazen manner.

It is undoubtedly true it does not at present obtain the attention it deserves, *but why should we deliberately provide a good target for the enemy instead of giving him an inconspicuous one*, and even in our present line in France, can anyone state that concealment of our gun emplacements, loopholes, communication, support trenches, strongposts, snipers' lairs, 2d-line trenches, etc., is of no importance?

Now exactly the same principles apply in concealing gun emplacements, etc., as in concealing fire trenches. But in my belief, so little importance is attached to concealment because the average

soldier fails to imagine the use to the enemy of aeroplane reconnaissance and how to foil the airmen, and not that concealment is of no value when trenches are near to each other.

As a matter of fact, the principles of concealment are of even greater importance when trenches are only a few yards away, owing to the fact that they are so much more difficult to carry out. If concealment is of no value the converse applies—visibility is no detriment—and if visibility is not a disadvantage, there is no reason why the top of the parapet of a trench should *not be as well-defined as the top of a wall*, as they are in Flanders in many cases; and if this is so, it does not need much mechanical ingenuity on the part of the enemy to fix their rifles and machine guns in such a way that they can sweep the top of the parapet from end to end, even at night. In fact, they can fire at night under these circumstances almost as accurately as during the day, and every time we man our parapets there is a danger of having a considerable number of casualties.

It is obvious then, the argument that concealment is of no value when the enemy's trenches are only a short distance off, can be reduced to an absurdity. Of course, no one would ever suggest when you are only a short distance away, that the enemy do not know where you are, but the great thing is *to confuse them as to the exact line of your parapet*. If you can only make them think that the top of the parados is the top of the parapet, you will have done something, and if, in addition, you site your trenches in an *irregular series of salients and re-entrants* instead of straight lines, the artillery of the enemy will not be able to get the range with the same amount of accuracy, and this will help to lessen your casualties.

Does anyone suggest that the use of dummies is of no value? The use of dummies means that you are creating a more attractive target for the enemy than that you wish to hide. In fact, it means concealment, and the value of dummies would be very much lessened if what you wished to conceal was just as visible as the dummy. Dummy trenches, dummy smoke, gun emplacements, flashes, dummy tracks, men's heads, loopholes, and dummy moving figures are obviously of the utmost value.

I have attempted to point out the value of concealment when trenches are only a short distance apart. In the case of *deliberate entrenchment* when you are awaiting an attack from the enemy, it is hardly necessary to emphasize its importance. When a short

time ago the Germans advanced through the Roumanian passes to Bucharest and beyond, do you think they would have had the same advantage from their superiority in shell fire if the Roumanians had line upon line of concealed trenches extending the whole distance back? *Can you imagine anything more likely to shatter the morale of soldiers than being suddenly fired at from a concealed position?*

I think, under these circumstances, the best troops in the world would attempt to make a bolt for it, and, if you have a good field of fire so that the enemy would have a considerable distance to run before they were able to get any cover, the probability is that under

Interior of trench, showing back of a man with a Lewis gun. Note the men in front attempting to fix rifles on the men in trench.

these circumstances very few of them would manage to escape.

There have been many examples of the value of concealment in the present war; in the first battle of Ypres, I was informed one battalion who had concealed their trenches in a turnip field (an exceedingly easy place to conceal a trench) brilliantly repulsed the enemy in consequence. The enemy by means of their aeroplanes discovered their presence, but only had a hazy notion as to their exact position; the consequence was that in spite of being shelled for 2 or 3 hours they had not a single casualty. The enemy then attacked in close formation. They were allowed

to advance within about 50 yards (when they became more or less entangled in loose barbed wire which was concealed amongst the turnips) before they were fired at. They then attempted to get away, but had so far to run before they were able to get cover that in front of this position 4,000 dead Germans were ultimately counted.

There can be no question of the desirability of concealment, but it is quite a legitimate matter for debate as to *whether it is always practicable or not.* I have not the smallest hesitation in saying this, that in the case of deliberate entrenchment, whatever the class of country may be, it is always possible to hide trenches from the air, and from the ground it can be done to such an extent that the enemy might almost fall into them without seeing them, and in *most kinds of soil they can be constructed without much greater expenditure of time, labor or material than is necessary in making existing trenches.*

In most soils 10 minutes extra labor is sufficient for the purpose. It is almost entirely a question of thought and experience and not of labor. Now, how is this to be carried out? The great secret of concealment is in the *imitation of nature.*

In my profession as a constructor of golf courses (and I have altered or constructed most of the Northern courses) any success I have attained I attribute almost entirely to my attempts to make every artificial feature of such a natural appearance that it cannot be distinguished from nature itself.

In attempting to get concealment exactly the same principle applies, the ground should appear as if it had been undisturbed by the hand of man, and to obtain this result there are one or two points which should be absolutely kept in mind. In the past there has been far too much attempt to construct trenches on geometrical instead of common-sense lines.

It is of the utmost importance to avoid all straight lines and angles. You never get straight lines and rectangles in nature. It may be argued that this is done at the present moment. If so, it is done by accident and not by design.

In my experience, I find it one of the most difficult matters to teach the average British workman to get away from the neatness and tidiness of straight lines and angles, and men who have had a training in military precision and accuracy are even more difficult to deal with.

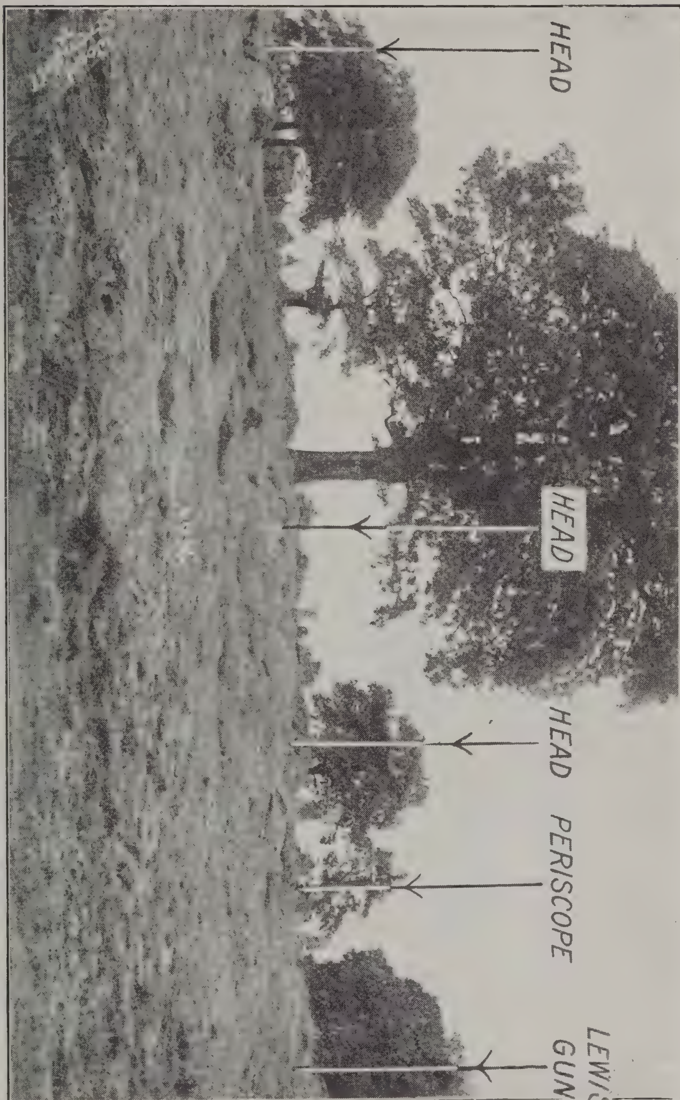
In trench making I do not wish to suggest that there should be

a want of method in the construction. What is wanted is a somewhat unusual combination, the combination of apparent untidiness and irregularity of the exterior of the trench with the most scrupulous exactness and neatness of the interior.

The parapet of the trench should absolutely harmonize with the appearance of its surroundings, and every raised portion of the trench should be indistinguishable from a natural contour. This is of as much, or even greater importance than the assimilation of color to that of the foreground. It is, of course, obvious that any raised portion of the trench should have exactly the same appearance and color as the foreground. In pasture land, for example, the sods should of course be replaced; in cultivated land the crops should be replaced; in ploughed land the top soil, which is invariably a different color to the sub-soil, should be carefully scraped to the rear and replaced on the parapet of the trench after the digging has been completed. Concealment in ploughed land is an extremely easy mater. Even at night, if not disturbed by the fire of the enemy, it is possible to conceal a trench in a position of this kind to such an extent that one might fall into it without seeing it. All that is necessary is to shovel the first 6 inches of soil to the rear, then throw up the parapet in an irregular uneven manner, in fact, in exactly the same way as a man would do if he were not thinking about it at all, and then when the requisite depth has been completed shovel the 6 inches of soil that has been placed to the rear over the parapet of the trench.

Concealment from aircraft is somewhat more difficult, but it must be remembered that artillery observers would find it an extremely difficult matter to recognize targets consisting of skilfully concealed positions from the description or photographs of air scouts viewing them from above. But in addition to this, it is found in actual practice that a skilfully concealed trench from the ground is also very much more concealed from above, and it is only possible for an observer in an aeroplane to spot it if he happens to be immediately over the trench. It is also found that straight lines and angles are much more visible and much more striking to observers in aircraft than irregular natural looking curves.

You can quite imagine that a trench of the type of the photograph I show you would be exceedingly difficult to locate by an aeroplane observer. It might quite easily be mistaken for a natural dip in the ground, and this particularly applies if the men have strict instructions to crouch down at the bottom of the trench when aeroplanes are flying over.



Trench—Photograph taken 10 yards away. The rifles and Lewis gun are sighted on the photographer. Half the trench was earth, the remainder sodded. Note: 1. It is impossible to define the line of the parapet; 2. it is impossible to spot the men's heads; 3. the loose lumps on parados and front of parapet which are likely to be mistaken for heads.

I am well aware that aeroplane photographs show every detail in a very striking manner, and even each traverse, a track leading to a gun emplacement, or a small ditch for a telephone wire, is clearly visible, but aeroplane photographs have their limitations; everything is flattened out, and it is impossible to distinguish between a dummy trench and the real one, and it is also impossible to tell whether the trench is occupied or not.

Much can be done to neutralize the value of aeroplane photographs, namely, the use of *dummies;* overhead cover of some kind, such as netting or rabbit wire threaded with grass; siting trenches in the line of hedges so that the marked shadow thrown by the hedge prevents the trench being spotted from above, the shadow at the bottom of the trench which is so strikingly visible from an aeroplane can be lessened in various ways; in chalk country, for instance, the black shadow of the interior of the trench is very marked between the white parapet and parados, if the parapet and parados are covered with the black upper soil and the chalk left exposed in the bottom and sides of the trench, the white chalk breaks up the black shadow and the whole trench becomes exceedingly inconspicuous from above.

In deliberate entrenchment, even in the winter months, it is nearly always possible to break up the shadow of the interior of a narrow trench in grass land by pegging down sods of long grass on the top of the interior slope so that the grass faces inwards and grows across the trench.

In consolidating captured positions, strong posts or new trenches can frequently be made by joining up shell holes in an irregular manner, so that the ground appears undisturbed from above.

Col. Solomon, the artist, who has done such excellent work in camouflage in France, points out that a reconnaissance photograph simply consists of degrees of black and white, light and shadow, and that a resourceful man knowing these principles of light and shade can do much to alter the appearance of real things and confuse them with their surroundings.

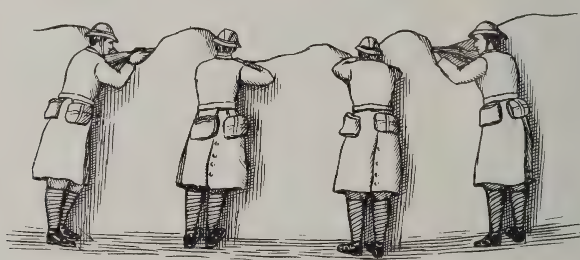
In addition to concealing the trenches, it is advisable *to hide the heads of the men* when firing from the trench. This can be done in various ways, such as by use of loopholes, the various types of which I shall describe later, but, in addition to this, it is an extremely simple matter to hide a man's head while actually firing over a parapet of a trench. This can be done partly by the way the parapet is made and partly by making the men's heads harmonize

Man in trench siting Lewis gun on photographer 4 yards away. Note: 800 officers and N.C.O's in groups during the day with rifle rests in front of them failed to fix a single rifle on this man 40 yards away. They rarely even fixed a rifle on the parapet.

in appearance with the foreground. If the top of the parapet of the trench is *made in irregular curves,* it helps to make this much easier.

As a general rule, the top of a trench is made in an absolutely straight line like the top of a wall or table. It is quite obvious that a man's head is then as easily seen as if he exposed it over the top of a wall. But, if instead of making it in a straight line, the top of the parapet is made in irregular waves (as shown in the diagram); the man then looks round the corner of cover, and his head merges with the raised portion of the parapet, and is not easily seen.

This is an old principle which we learnt from the Boers; we all know that the Boers instead of looking over the top of a rock, looked round it. Not only was the head very much less visible, as it did not appear on the sky line, but it was much better protected,



as it was only vulnerable by fire from one flank, and if he were content to fire obliquely to his flank, his head was absolutely protected by the rock in front, and he could only be damaged by an enemy firing in exactly the opposite direction, an extremely unlikely contingency.

It is quite possible to adopt the same principle in trench making, as in making a parapet in the form of waves. There are certain precautions to take, however, in making a wavy parapet; you must be certain that the wave you fire round is bullet proof, and if not bullet proof, you should proceed to make it so by methods which are subsequently described. You should also make sure that the whole of the foreground is covered by rifle fire from the trench. In hiding men's heads, in addition to having a wavy parapet, you should always take care that there is a background of some kind. and if there is no natural background you should proceed to make one in the form of a parados.

In addition to the form of trenches you make, you should take care that your head harmonizes in appearance with the remainder of the field. No one, except a natural born idiot, would ever put his head over the parapet of a trench with a field service cap on. It is not at all a difficult matter to make your head harmonize with the foreground. For example, in a turnip field you should attempt to make your head look as much like a turnip as possible; in a cabbage field as much like a cabbage as possible, and in pasture as much like a sod as possible.

The simplest form of mask to use is an ordinary sandbag, with two holes for the eyes, and the corner stitched down, so that they will not be prominent. The sandbag can then be covered with part of the actual parapet. In grass land, it should be covered with grass; in an ordinary mud parapet, the sandbag should be smeared with mud, so as to give it exactly the same appearance as a projection of the parapet.

The parapet should be made as rough, irregular, and rugged as possible. It is an extremely simple matter to do this; in fact, it is easier to make a parapet irregular than neat and tidy. Existing parapets can be altered under actual service conditions in France or Flanders, and can be made much more inconspicuous, and, at the same time, have an irregular and rugged appearance. All that is necessary is to accumulate the dark colored top soil of plough land or the sods of pasture land in the trenches during the daytime, and at night make the parapet as irregular as possible, and then cover it with the top soil or sods which have been accumulated in the trenches during the day.

The effect is very striking, as trenches can be made exceedingly inconspicuous in one night. The enemy, waking up in the morning, find that they have a very bad target in front of them, instead of a very conspicuous one, and they also find it is absolutely impossible to spot the men's heads as they are firing over the parapet.

This is an extremely important subject, and is a subject which has had far too little attention. It is the sort of thing that is more or less looked upon as playing at soldiering, whereas its importance can hardly be exaggerated. It is such an extremely simple and easy matter, and I have not the smallest hesitation in saying this, that no man firing over the parapet of a trench should ever be visible at a distance of 50 yards. It is a thing quite capable of proof and I should be very pleased to demonstrate it to you.

While aiming a rifle at the pit of the stomach of a man stationed 50 yards off, I have never yet been spotted by him, and in

trying this experiment I invariably called out to him and invited him to come nearer and nearer, and it is extremely rarely that anyone spots the position of my head until they get within 12 or 15 yards away.

If men during their training were instructed in tricks of this kind, there would be much fewer casualties in our ranks, and we should be able to inflict much more loss to the enemy.

A friend of mine who is a chemist and is continually visiting different portions of our line in connection with the use of asphyxiating gases told me, in the summer of 1915, that although the Canadians and two Irish battalions were worrying the enemy with all sorts of slim tricks from early morn till late at night, we were far less active in this respect.

If we only understood what an extremely easy matter it is to expose one's head over the parapet of the trench without being seen by the enemy, we should have very much greater confidence in doing so, and our snipers would show much greater activity and cause many more casualties in the ranks of the enemy.

The doctrine of leaving the enemy alone—provided they will do likewise—is a most pernicious one. Those units who adopt what might be termed an aggressive defensive not only have the satisfaction of becoming top dog, and inflicting more casualties in the ranks of the enemy, but, eventually, actually lessen the number of casualties they have themselves, and their morale is such that they are better fitted to undertake the offensive when the time comes for them to do so.

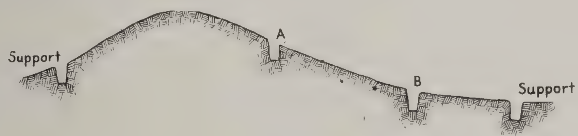
In concluding my remarks regarding this subject, I wish to emphasize the fact that although in the present conditions in Flanders total concealment is impossible, yet there are *degrees of concealment which are easily carried out.* It is just as easy a matter to construct your trenches in an irregular series of salients and re-entrants, and with irregular and rugged parapets and parados, as in straight lines and angles. It is also not difficult to provide an inconspicuous target for the enemy, instead of a regular well defined one. The parapet of the trench can be readily made exactly of the same color and appearance of the foreground by accumulating the top soil in the trenches during the day, and shovelling it out at night.

AN EXTENSIVE FIELD OF VISION AND FIRE.

During the present war, it has been discovered that owing to the accuracy and rapidity of fire of the modern rifle, a large field

of fire is not as necessary as it was in the past. We have found that, provided we had good obstacles, we were able to repulse an attack of the enemy with a field of fire of as small amount as 50 to 100 yards, but the important thing to remember is that the ground immediately in front of your trench, at any rate for the first 50 yards, must be completely swept by your rifle fire. It is essential that there should be no dead ground (that is, ground not swept by your fire) within the first 50 to 100 yards in front of your trench. It is now generally agreed, we have been carrying this somewhat to extreme, a field of fire is as necessary as ever it was, provided that you have concealment in addition.

In the winter of 1914-15, in great part, owing to our inability to get concealment in front of the crest of a hill, and owing to the fact that we had not then grasped the fundamental principles of concealment, we had a perfect craze for hiding our trenches behind the crests of the slopes, in which position we felt comparatively safe from the artillery of the enemy. The disadvantages of this were pointed out at the time, and, if we had more



specialists on the important subject of trench-making, it should have been quite possible to have foretold what was likely to happen and what has actually happened on most of our line.

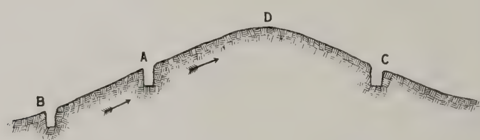
The German fire trenches are on the crest of the slope at *A;* we are on the reverse slope at *B;* during the day our artillery cannot do them much harm, owing to the fact that they hold their fire trenches with a small number of men and a large number of machine guns. At night they push their men up, and with their fixed rifles and machine guns are continually firing at our communications and causing scores of casualties to our reliefs, etc. We, on the other hand, cannot do them much damage, owing to the fact that their communication and support trenches are on the opposite sides of the slopes in positions impossible to get at with our rifles and machine guns. The consequence is that instead of this being a war of attrition, as Hillaire Belloc stated in 1915, with a greater number of casualties in the ranks of the Germans, I strongly believe at the time he wrote the evidence was all the other way, owing to the fact that the Germans had the commanding positions in most of the line and were able to hold these commanding positions with a small number of machine guns. I am of opinion that in every-day trench

warfare, where the commanding positions are in the hands of the enemy, we are suffering a far larger number of casualties than they.

I do not, however, wish to exaggerate the importance of the commanding positions, and I do not wish to state that a trench behind the crest of the hill is always wrongly placed. Before I was gazetted, I wrote on this subject in the winter of 1914-15, and in reply to my article in *"Country Life,"* a well-known staff officer replied in the following terms:

> Dr. Mackenzie goes on to say we have been reduced to concealing our trenches in little valleys, or on the reverse slope of hills, which is to a certain extent a confession of failure. (What I stated was a confession of failure of concealment in front of the crest of the hill.)

Now I know an instance that occurred at the Aisne when we were being constantly and fiercely attacked. We were reduced to conceal our trenches on the reverse slope of a hill—I wonder if you will think this is a confession of failure. This is a rough sketch of the piece of ground I am thinking of —



A certain battalion took up a position at *A* and dug careful trenches, using all the time and skill they had to disguise them and combine maximum fire effect with concealment. They were practical trenches, and followed almost all the points laid down by Dr. Mackenzie. Straight lines were avoided as much as possible, and the trenches were sited with due regard to the slope of the ground. Also, they were so constructed that each trench should help its neighbor by its fire, and the fall of one trench would not of necessity mean the fall of all; in fact, they were carefully made. In the short time there was, a little (much too little) wire was put on the front in the form of trip wires; there was not time for a more formidable obstacle. These trenches were occupied and very shortly afterwards were being searched for by the enemy's guns. At first, the shells went all over the place—doing no harm at all—eventually, though I suppose by means of aeroplanes, of which at that time the enemy had a good many, perhaps by the wire in front showing up, per-

haps owing to the careless movement of a few men here and there, or even the presence of a few empty tins (you know the British soldier is hopelessly careless, and officers cannot see everything); whatever it was, the shells soon began to get unpleasantly close, and the German infantry attacked. So far, we had suffered little from the bombardment, and the advancing Germans got a beastly time of it; they were stout-hearted brutes, though, and by nightfall had established a line of trenches from 200 to 400 yards to our front at about point *B* in the diagram. Concealment was now more or less at an end. When men are only a short distance apart, even in Dr. Mackenzie's trenches, they find out each other's position after a time, and, if they do not find out by field glasses, they will by sending out men at night. The result was, of course, that our life was in future very undesirable.

The German artillery observing officers presumably came up to *B* and, as we were undoubtedly out-gunned at that time, we had a miserable existence. Eventually, it was decided that the position was untenable, and orders were given for reserves to prepare trenches at *C*. This was done, and one night we left *A* and got into new trenches at *C*, which left much to be desired, but were at once improved. A very few hours later, the Germans attacked, finding *A* empty they came up to *D* and there showed up against the sky line most beautifully even in the dark. They got little further and attack after attack failed, even though the distance from *C* to *D* was only about 70 yards. So many were killed that our men went out to make lanes in the piles of dead bodies, so as to give the next attack a clear run to death. Next day we were shelled, but the range and direction were rotten compared to when we were at *A*, and even the aeroplanes did little to improve their shooting, for their artillery officers could not get direct observation on to our trenches as they did from *B* when we were at *A*. Our guns made the top of the hill *D* too hot to be held, and a deadlock followed. We held that position for three weeks, and the Germans never got further. The forward position we held only for a few hours. Do you think it was a confession of failure to move back to *C*?

The above is a striking example of the success attending the siting of a trench behind the crest of a hill, and it was owing to brilliant successes of this kind that we had such a craze for siting trenches in this position. But, as pointed out before, there were obvious dangers attached to positions of this nature, and it was not difficult to tell the trouble it might ultimately lead to. The

proper place, as a general rule, to site a fire trench, is in front of the hill, provided you are able to conceal it in this position, and also able to conceal your communication trenches running over the crest to the support trenches behind. A great deal of our hesitation in siting trenches in front of the crest of the hill has not only been due to the fact that we have been unable to hide the fire trenches, but also that we have had some difficulty in hiding the communication trenches running back over the slope. Communication trenches in this position are in reality exceedingly easy to conceal; the method of doing this I will describe later.

To summarize: siting a trench on the reverse slope was, admittedly, of advantage when it was a surprise for the enemy, and it might occasionally be of value to-day when fighting a rear-guard action, especially if the enemy have a great superiority in artillery, but it is absolutely a wrong place when the enemy have dug themselves in in the commanding positions above you, and it is quite a debatable point whether in those parts of our present line in France and Flanders, where the enemy have obtained the commanding positions it might not be advisable (if we are unable to occupy these commanding positions) to retire a short distance so as to obtain the advantage of a large field of fire.

Experience in this war has confirmed this view. The latest official pamphlet of trench warfare unhesitatingly condemns the siting of trenches on reverse slopes. The disadvantages are:

1. The enemy get the best observing positions.
2. The occupation of the high ground gives a feeling of superiority which reacts favorably on the morale of the troops.
3. The occupation of high ground enables the supports to be kept under cover behind the crest.
4. The commanding positions enable you to inflict more casualties upon the ranks of the enemy, as their communication, support trenches, and roads behind their lines are all under your fire.
5. It is easier to attack down hill than up.
6. It is easier to gas down hill than up.
7. Trenches in commanding positions are more easily drained.

(See articles in "*Country Life*" of March and April, 1915.)

A MAXIMUM AMOUNT OF PROTECTION FROM RIFLE FIRE AND THE VARIOUS TYPES OF SHELL FIRE.

In studying the penetrating effect of the modern rifle bullet on the parapet of a trench, it is absolutely essential that you should

be well acquainted with the penetration table which is described in every modern book on military engineering. The penetrating effect of a bullet of the short Lee Enfield service rifle at 30 yards range is as follows:

Steel plate	$\frac{3}{16}$″
Wrought iron	¾″
Shingle	6″
Coal	9″
Brickwork	9″
Chalk	15″
Sand (confined)	18″
Sand (loose)	30″
Hard wood	38″
Soft wood	58″
Earth	48″
Earth rammed	60″
Clay	60″
Dry peat, or sods	80″
Snow	6′

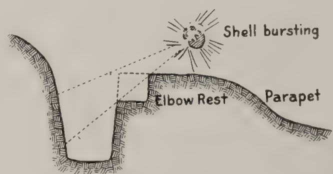
The penetrating effect of the German bullet is somewhat greater, and recently the Germans have been using a bullet which has an even greater penetrating effect than the ordinary one.

It will be noticed there are some very striking points about this table. Does not it seem rather extraordinary that there should be such a striking difference between the penetrating effect of a bullet on sand and on clay? If you push a stick into sand, it penetrates it with the greatest ease, whereas in clay some force is necessary to push it through. You would also naturally think that wood would have a very much greater stopping effect on a bullet than sand, whereas, the precise opposite is the case. As far as I know, there has been no explanation given of this striking difference in any of the text-books on military engineering, but it may help you to remember the penetrating effect of a bullet on these different materials if I suggest a theory to account for it.

I think these differences can be explained by what one might call the "vacuum" theory. If you take a syringe and pull up the piston, it comes out with the greatest ease, but if you put your finger on the nozzle of the syringe, the air is unable to fill the vacuum which is created behind any moving object, and it is impossible to pull out the piston any great distance; the same thing occurs when a bullet penetrates sand, and the particles of sand fall behind the path of the bullet and by creating a vacuum cause a drag on the

back of the bullet. In clay, on the contrary, the bullet leaves an open channel behind it, and no vacuum is created behind the path of the bullet, and therefore it penetrates the clay much more readily. The same theory would account for the difference between loose earth and rammed earth; if earth is loose, the particles of soil to a certain extent drop down behind the path of the bullet and the air is unable to enter; in the case of rammed earth, an open channel is left. If we consider this theory in the case of sand confined and loose, it will also help to explain why the effect is precisely the opposite of ramming earth. If sand is confined, there is no open channel left behind the path of the bullet; in fact, one would expect the particles of sand to drop down all the quicker.

I simply give this theory for what it is worth to help you to remember the penetration table, but I am bound to admit that one of the best known living authorities on the subject of musketry does not agree with this theory.



In studying protection from various types of shell fire, it is necessary to understand the effect of various kinds of shells. Shell fire may be divided roughly into two kinds—the common shell and the howitzer shell. The common shell may be subdivided into three kinds, the percussion fuse, the time fuse, and the shrapnel time fuse. In the percussion fuse the shell penetrates the ground before bursting, so that the fragments of shell tend to burst upwards. The consequence is that even if a shell bursts quite close. you are comparatively safe when lying down.

Shrapnel.

Shrapnel of common shell invariably bursts slightly downwards and forwards.

It is therefore obvious that the steeper the upper portion of the interior slope of the trench is, the more protected you are from shrapnel. Shrapnel has roughly a radius of 25 yards in width. 200 yards in length.

Howitzer shells may be also subdivided into two kinds, the

common shell with percussion fuse and the shrapnel time fuse. The angle of descent of the howitzer shell may be anything up to $\frac{1}{1}$.

In constructing a trench from a point of view of protection from the various types of shell fire, it is obvious that no trench can be absolutely safe from a howitzer high explosive shell, such as the shell known as the Jack Johnson, Black Maria, or Coal Box, but a great deal can be done to lessen the danger caused by the effect of these shells. It is obvious that the more concealed your trench is, the less it will be likely to be hit by the enemy's artillery fire.

It is also clear that the deeper and narrower the trench is, the safer it is. A trench of double the width is much more than twice as dangerous as a narrow one. A trench of which the interior slope is vertical at the top is extremely safe against shrapnel from the front.

A parados (back parapet) is desirable for the prevention of splinters and the back blast of high explosive shells. In regard to protection from enfilade or oblique fire, it is obvious that a straight trench without traverses is extremely dangerous. It is therefore necessary to construct a trench of a sinuous outline or with traverses, and the more frequent the traverses are the safer the trench will be. There is also better protection for the heads of the men if the portion of the traverse opposite the channel of the trench is somewhat higher than the parapet. To summarize, the deeper and narrower and more heavily traversed a trench is, the safer it is. There are, of course, obvious disadvantages of narrowness, such as decreased comfort for the men, difficulty in moving wounded, difficulty of men passing each other, and difficulty of supervision. It is necessary to hit the happy medium. As a general rule, when awaiting an attack from the enemy, the trench should be narrow. If the enemy are held up and construct trenches within a short distance away, your trenches can be afterwards widened for the purpose of increasing the comfort of the men, etc.

There is one big advantage of narrowness which, as far as I know, has not been pointed out before, and which only applies in the case of raw troops, and that is that in the case of a narrow trench, it is much more difficult for them to run away, as, if it is so narrow that the men even have a difficulty in passing each other the man who wishes to bolt would have to knock down every man between himself and the next communication trench before he would be able to get away.

Note. In a pamphlet captured from the Germans, it is argued that the concussion in the vicinity of a deep narrow trench causes the sides to fall in, burying the men occupying the trench. There are usually two sides to a question, and there is a good deal to be said in favor of this argument. It depends, however, on not only local conditions, the nature of the soil, the use of rifle grenades, the size and kind of shells usually used, etc., but to a much greater extent on the way the trench is constructed. It is explained later that men are likely to undercut the bottom of the interior slope so that it is extremely liable to fall in. All trenches should, as in natural slopes, be made with a wide sole, as subsequently described. Concealment from the air is clearly much easier in the case of a narrow trench than in a wide one. It also takes less labor to construct.

EFFICIENT DRAINAGE.

The question of drainage is a most important point, possibly of even greater importance than anything else. Trenches full of water are almost worse than useless, and men would prefer the risk of bullets to standing waist deep in water by day and night. The question of drainage should be taken into consideration in siting the trench in the first instance. The trenches should be sited in such a position that it is possible to get a fall to a lower level. From a drainage point of view, it is much better that the trenches should be near the top of a slope than in a valley. Any existing drains, such as the ordinary field drains, should be made the fullest use of, and by studying closely the natural drainage, a considerable amount of labor can frequently be saved. In this country, the ordinary agricultural main drains are rarely lower than 3 feet or 3 feet 6 inches. In very wet land, you should therefore attempt to keep above the level of the main agricultural drain, and to do this it is sometimes necessary to make the trench a little wider than usual, or to make a borrow pit, so as to get sufficient soil to form a high parapet.

In cases where it is necessary to go deeper than the position of the main drain, a considerable amount of labor can sometimes be saved by running a drain from the fire trench to catch the main on a lower level, or by constructing the communication trench in such a position that it will do so. In draining a trench, one should always start at the lowest level and work upwards. If pos-

sible, it is advisable to use the field level when the fall is not quite obvious. Sometimes a trench can be drained by constructing a sump at a lower level. A sump is particularly useful in land where there is a deep porous stratum.

It is of the utmost importance when the drainage system has once been completed to give it constant attention, seeing that the trenches do not get blocked. Whenever a heavy shower comes on, men should be sent out in the middle of the rain to keep the drains running freely; this would probably save days or even weeks of labor afterwards. What frequently happens is this—a small portion of the drain gets blocked, this block causes an accumulation of water which gives rise to a portion of the trench falling in; larger blocks occur until more and more of the trench falls in, which necessitates a considerable amount of labor afterwards, whereas this could be easily avoided by a little attention in the first instance.

A TRENCH SHOULD BE DESIGNED TO FACILITATE AN ATTACK AND TO PROVIDE A MAXIMUM AMOUNT OF FIRE CONTROL AND FIRING ROOM IN THE TRENCH.

To facilitate an attack, an easy method of getting out of the fire trenches is by means of the trench grids; for instance, they can be constructed in such a way that they can be lifted up and used as ladders to get over the parapet. Means should be adopted to allow the concentration of a large number of men in the neighborhood of the fire trenches for the purpose of an attack. This is usually done by means of Slit Trenches leading off from the communication trenches.

In regard to fire control, it is obvious that the straighter and wider a trench is the easier the control. But, this, of course, is directly opposed to the principles adopted for protection from the effects of shell fire. The more sinuous and more heavily traversed a trench is, the more difficult the fire control; but, on the whole, it is very much better to sacrifice fire control for the purpose of getting increased safety. Much may be done in increasing the fire control by other means, such as supervision trenches; that is, trenches made in loops immediately behind the parados. These supervision or lateral communication trenches are particularly useful when the fire trenches are narrow, as they enable the men to be relieved much more readily, also the officers to move more easily from one part of the trench to another. Frequent traverses or recesses diminish the firing room in a trench, but, in these days of machine guns, it is often advisable to sacrifice firing room for the purpose of increased safety.

Note. It is clearly of vital importance that an attack should be a complete surprise to the enemy. Artillery, trench mortar, machine gun emplacements, assembly trenches, etc., should of course be constructed and completely hidden from the ground and the air before they are occupied. Dummy emplacements and dummy assembly trenches should be constructed in other parts of the line where it is not intended to attack.

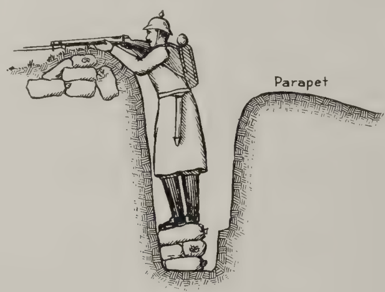
IN THE EVENT OF RETIREMENT THE TRENCH SHOULD BE OF SUCH A KIND THAT IT IS OF LITTLE VALUE TO THE ENEMY.

Much may be done in constructing a trench to make it of such a kind that, in the event of the enemy capturing it, it can easily be retaken.

The importance of making traps for the enemy can hardly be exaggerated. If you are confident that in the event of the enemy getting into your fire trenches, you can invariably wipe them out, the line can be held with much fewer men (possibly even a quarter of those we use at present); not only would there be much fewer casualties, but more men would be available for the offensive at the deciding point.

It must be borne in mind that means should be devised not only to wipe the enemy out if they get into the fire trenches, but they should also be prevented from continuing the attack up the communication trenches and also across the open towards the supports.

The whole scheme of trenches, even including sumps for drainage, the construction and position of dug-outs, etc., should all be arranged with a view of assisting in repulsing an attack of the enemy.



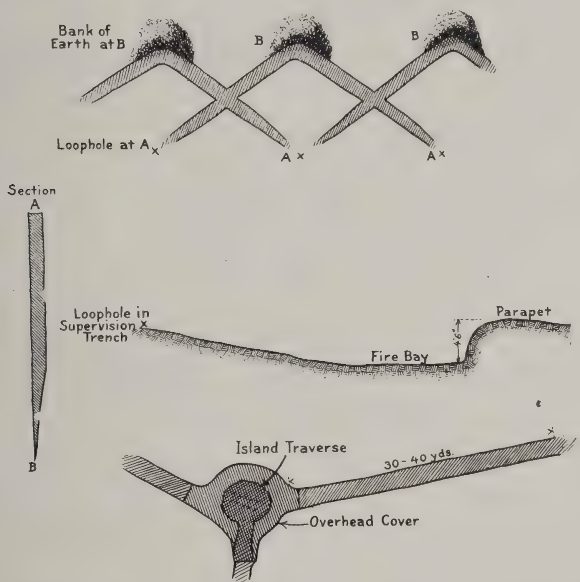
It is an easy matter to design fire trenches of such a kind that they do not afford any cover to the enemy; for example, in the case of breastworks, or semi-breastworks, you can have a parados which, although it is sufficiently thick to lessen the danger from the back-blast and splinters of high-explosive shells, is not so thick as to prevent a bullet from penetrating it.

What are called parados boxes have been used in Flanders from this point of view. They consist of boxes about 1½ feet wide, and are filled with soil and are obviously not thick enough to prevent a bullet penetrating it. A much more subtle method of doing this is to construct a parados which is apparently bullet proof but is in reality not so. This may be done by forming a parados consisting of bags full of straw, grass, etc., and covering them over with a light layer of soil. A parados of this kind has several advantages. It is sufficient to stop the back-blast and splinters from a high-explosive shell, and, if the shell bursts so near that the parados is blown into the trench, the bags of straw falling on the men cannot do them much harm. If the enemy capture the trench, owing to the thickness of the parados, they naturally assume that it is bullet proof, and make no attempt to make it so. The consequence is that your bullets will penetrate the parados without them perceiving the reason

for it. It is always advisable to have some point at a higher level in your communication or support trenches where you can place a machine gun, so that you can fire at the back of the fire trench in the event of its being captured by the enemy.

A type of fire trench which is exceedingly easy to get back from the enemy is the Zigzag type. This is not a good type of trench unless it is well constructed. It was condemned in Flanders because, to use an Irishism, it was so likely to be enfiladed from the front. The objection can be easily got over by throwing up all the soil at the angles, as shown in the diagram.

All the fire bays can be covered by fire from loopholes, in the super-

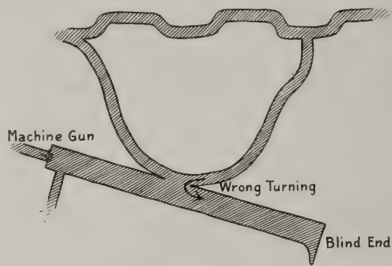


vision trenches. This can be facilitated if each bay is continued in an even slope up to the ground level towards the loopholes of the supervision trenches.

There are other ways in which you can make traps for the enemy in the event of their capturing your trenches. For example, by mining your fire trench in such a way that you blow them up if they capture it. Various traps can be made in the communication trenches; for instance, you can have a straight length of trench about 40 yards long, as shown in the diagram, with an island traverse at the far end, the traverse being perforated by loopholes, an overhead cover being placed over the traverse, and the adjoining portion of the communication trench for the purpose of hiding the loopholes and rifles of the men behind the traverse, also to give the enemy the impression that it was a blind trench leading to a dug-out. A couple of men with rifles and loaders could hold a communication trench of this kind against any number of the enemy. They

would only be able to attack in single file, and if the straight portion be 30 or 40 yards long, they would be unable to throw their bombs from the corner as far as the overhead cover.

There are numerous other ways of devising traps for the enemy in the communication trenches, such as the following:

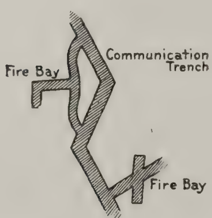


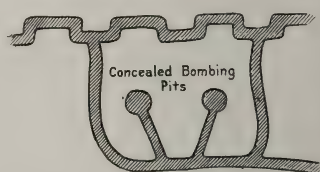
The enemy must also be prevented from coming across the open, by fire from the support trenches. The support trenches should therefore be constructed exactly the same as the fire trenches, and should have obstacles perfectly concealed in pits in front of them.

The communication trenches should also be designed so that lateral fire can be brought to bear across the open ground.

BOMBING TRAPS.

A plentiful supply of bombs should always be available. Concealed lairs for bombers should be constructed behind the fire trenches, and should be placed in such a position that the whole of the fire trenches are





covered from these concealed pits. In this way it is an extremely easy matter to bomb the enemy out of your own trenches in the event of them getting in.

The enemy would not have the faintest idea where the bombs were coming from, and, in any case, would have an extremely small target to aim at.

The communication trenches should also be made so that it is easy to bomb towards your own fire trenches—difficult in the opposite direction.

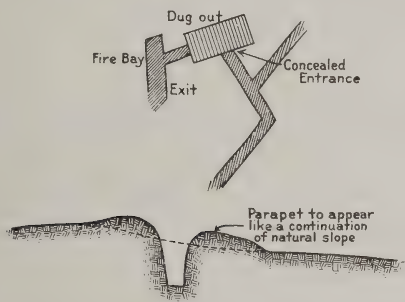
All dug-outs should be sited and designed for the purpose of repulsing the enemy. They should have two openings, for the purpose of the men being able to escape in the event of one opening becoming blocked by

shell fire, the second opening should lead to some post of military value, such as a small strongpost or fire bay between the communication trenches.

FIRE TRENCHES.

Siting of Fire Trenches.

We have already to a certain extent discussed the siting of fire trenches in reference to their position in front of or behind the crest of a hill. It has been pointed out in spite of the brilliant successes that have occasionally attended the siting of a fire trench behind the crest of the hill that, provided you have sufficient confidence in your men in being able to conceal a trench, the front of the crest is, in the first instance, the proper place to site a fire trench, not only for the reason that you have a great field of fire and get the best observing position, but also the fact that if your fire trenches are sited in front of the crest, you are able to *keep your supports under cover behind the hill.* The siting of a fire trench is a much



simpler matter than would appear at first sight. As a general rule, the best place to site a trench is behind a slight fold in the ground. In fact, in the exact line where men would naturally lie down when waiting an attack from the enemy.

One takes advantage of a natural fold, not only for the purpose of saving labor in the construction of the trench, but also from the point of view of concealment.

The most important point in siting a trench is to see that there is *a field of fire in the immediate foreground* and any portion in the foreground which is not covered by the fire from the trench immediately behind it, should not only have much more effective obstacles in this position, but, in addition, care should be taken that this dead ground is covered by oblique fire from the flanks. In siting a trench it is of the utmost importance that you should lie on your face to see that there is a field of fire in the immediate foreground. I often see officers attempting to site a trench from the top of a horse.

It is difficult, or even impossible, to site a trench properly except when lying down.

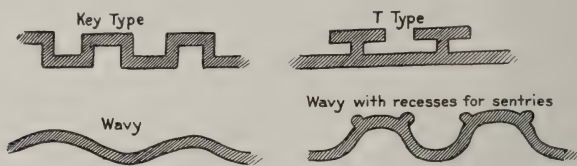
The question of *drainage* should always be taken into consideration in

siting a trench. The trench should be sited in such a position that there is no difficulty in draining any water from the bottom of it to a lower level.

Marked points on the map or positions easily located by artillery observers should be avoided when siting a trench. For example, it is not by any means always advisable to site a trench along the line of a hedge, front of a wood, the side of a road, near a prominent church, or house, and even near high trees. It depends, however, on other circumstances and particularly depends on the ability of your men to construct the trench in such a way that they are able to get concealment in the open. The front edge of woods, the line of hedges, etc., are precisely the positions which the enemy would expect you to entrench, and which are almost bound to be sprinkled with their artillery fire. The consequences are that if you are able to conceal your trenches in positions least suspected by the enemy, it is advisable to do so. However, this, as I said before, depends entirely on your ability to construct your trenches properly.

In regard to hedges, it must be remembered that a trench in the line of a hedge, is very difficult to spot from aircraft. If hedges are numerous, it is often quite the right place to site a trench.

The various types of trenches which are being used in Flanders are the following:



It is not advisable to be dogmatic in regard to the type of trench one should adopt; in fact, it is advisable to avoid fixed patterns. Variety is an advantage in order to confuse the enemy as much as possible. A good type of trench is the wavy type with traverses. Waves should not, however, be too marked, owing to the danger of your men firing into the neighboring portions of their own line.

The wavy type of trench has many advantages: it is easy to conceal, as waves have a much more natural appearance than straight lines and angles. It is easy to construct in such a way that it harmonizes with the natural contours of the ground. It can be utilized much more readily for obtaining oblique fire, and it can be constructed in such a way that it gives much more adequate protection against enfilade fire. It also enables you to get a greater number of rifles in your trench than any other type.

In regard to width, as remarked before, the narrower a trench is, the safer it is, so that in the first instance, while you are awaiting an attack from the enemy, a trench about 2 feet 6 inches wide and 4 feet 6 inches deep is sufficient. When more time is available, it can be subsequently widened and deepened, part of the bottom of the original trench being used as a firing step, the other part being deepened behind to 6 or 7 feet or more.

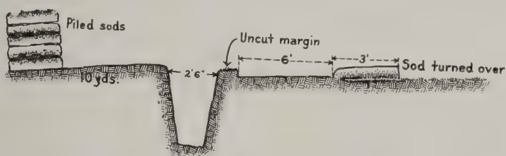
I shall now attempt to describe in detail the construction of a trench of this kind in pasture land.

Two feet 6 inches of sods are first removed from the proposed site of the trench.

The sods are removed 10 yards to the rear and piled up grass to grass and earth to earth; this prevents the grass becoming soiled. Then a further 6 feet, or two shovel lengths of sods, are removed from the front, leaving a small margin of uncut turf to mark the boundary of the trench. Some of the men can now commence excavating and throwing the earth up to form the parapet. While they are doing this a few men can be retained paring a further 3 feet of sods in the position shown in the diagram.

In pasture, where there is plenty of fibre, all the sods can be turned over.

The last 3 feet of sods should not be removed, but should be *undercut and turned over towards the front like a lid.* They should not be rolled



over like a carpet, as this tends to soil the grass. The object of turning over this last 3 feet of sods is that when replaced it helps to make the rise of the parapet emerge imperceptibly with the foreground.

After a trench has been dug the requisite 4 feet 6 inches, the sods should be replaced.

Whilst excavating a trench it should be constructed with a slope so that, although $2\frac{1}{2}$ feet wide at the top, it shelves down to $1\frac{1}{2}$ feet at the bottom. If the slope is constructed properly, the side of the trench will usually remain standing without revetting material. In making a slope of this kind, it is of value to study the *kind of slopes which occur in nature* and which remain standing for a considerable number of years, for example: if we study closely the slope of a bank of a stream, or a quarry, or the slope of a sand dune, we find that the *lower portion slopes considerably whilst the upper portion is vertical, or actually overhangs, as in the diagram;* and in constructing the slope of the interior of the trench it

is advisable to do it in the same way. The important thing to remember is that the lower 2 feet or so should slope considerably. The upper portion can with advantage be made vertical, or even actually overhang. This gives you very effective protection against shrapnel. The tendency of most soldiers is to make the trench in precisely the opposite way. They usually give the upper portion a considerable slope; the lower portion is vertical or is even very frequently undercut; a trench of this kind is bound to fall in.

If little points of this kind were remembered, tens of thousands or possibly even millions of pounds might have been saved in revetting material during the course of this war.

The cause of trenches falling in is due to the fact that in many cases the slopes have not been made properly, also that *water has been allowed to accumulate in them.* It is of the utmost importance therefore that no water should be allowed to accumulate in a trench even for a few hours.

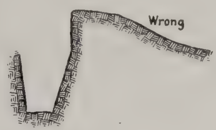
Note. During heavy rain, men should be sent out at once to keep the drains working, this will save days of labor afterwards.

In throwing the soil up to form a parapet, the parapet should be made in such a way that it is felt at the top for a space of 6 feet and has a gradual natural slope for the last 3 feet to meet the foreground in front. The parapet, for the purpose of getting adequate protection from rifle and shell fire, and for the purpose of getting greater concealment, should be kept as low as possible (provided there is a good field of fire, 9 inches or 1 foot is usually sufficient). The top of the interior slope of the parapet should be made nearly vertical, and this can be done by revetting it up with sandbags or sods; there will be 2½ feet of sods to spare for this purpose.

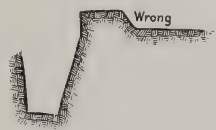
It is not necessary to have an elbow rest. During this war there has been an increasing tendency to do away with elbow rests, owing to the fact that they make the trench so much more vulnerable to shrapnel.

The commoner mistakes that are made in constructing the parapet of a trench are as follow:

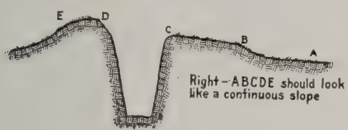
If the parapet is made of the above shape, it can obviously not be concealed, and is not even bullet proof. Or else it is made thus:

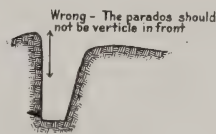


The parapet runs up in a straight line to the top of the interior slope. A parapet of this kind can also not be concealed, and the upper portion is not bullet proof. Another common mistake is the following type, which is often described in the text-books.



This is probably bullet proof, but owing to the artificial straight lines and angles would be exceedingly visible. The right kind of a parapet is the following:





It will be noticed that the portion *A-B*, which is rising from the foreground, has a tendency to be slightly concave, and is not in any way convex. There is another important thing which must be borne in mind in constructing a trench. When an artist is attempting to produce the appearance of a rise on a flat surface, he shades the lower portion a darker color than the upper. In constructing the parapet of a trench, it is advisable to do the reverse. The portion of the parapet rising from the foreground should be light colored, the upper portion of the parapet should be darker in color. This effect can be produced with the aid of a little dark soil. The sods used for the portion of the parapet rising from the foreground should be very clean, and, for this reason, as suggested, the last 3 feet of sods should be turned over like a lid. In the higher portion of the parapet, dirtier sods can be used, or, if pressed for time, need not be covered at all. The important thing to remember is that the slope of the parapet rising from the foreground should be carefully sodded over with clean sods. The upper portion of the parapet can be left unsodded or simply a few old sods thrown on in any sort of rough way.

I do not wish to suggest that if you have enough time to complete the trench properly that you should not sod over the whole of the parapet, but all I wish to point out is that a certain degree of concealment can be

obtained by simply replacing the sods on the portion of the parapet which rises from the immediate foreground.

If this principle is borne in mind, it is possible to construct a trench on even a flat lawn which you would fall into without seeing. This might appear at first to be impossible, as it would naturally be argued that a hole in the ground on a flat lawn is in itself visible, but the point is that your parapet blocks out the view of that hole, and, if the sods are cut and replaced extremely carefully and shaded in the manner I have described by simply throwing a few shovelfuls of dark colored earth on the upper portion of the parapet, you can get the opposite effect to what the artist is attempting to reproduce when he makes the appearance of rising ground, and the parapet does not appear as a rise at all.

From the above description I do not wish to mislead you into thinking that as a general rule the sods should be cut and replaced as carefully as would be done by a landscape gardener; on the contrary, it is quite sufficient for the purpose if the sods are cut by inexperienced men with the ordinary shovel.

It is not in any way necessary to sod the parapet of a trench with the same neatness and regularity as you would do in the case of a lawn. The whole thing can be done perfectly easily by any soldier who is able to handle a pick or a shovel; in fact, the more carelessly and untidily the parapet is sodded the better. The parapet should be rugged, irregular, and have a natural appearance. Some of the sods may be deliberately turned upside down; this makes it all the more difficult to distinguish a man's head when appearing above the parapet.

I have previously stated that the type of trench I prefer is the wavy trench with recesses and traverses; the recesses may be made for either one man or two, and it is quite sufficient if *sufficient number of recesses are made for the limited number of sentries holding the trench under normal circumstances.* It will be seen from the photographs that the higher portions of the waves of the parapet are constructed opposite the middle or left of the side of these recesses; the man in the recess, therefore, either fires obliquely to his flank or leans over to the right to fire round the wave of the parapet, using the edge of the recess as an elbow rest.

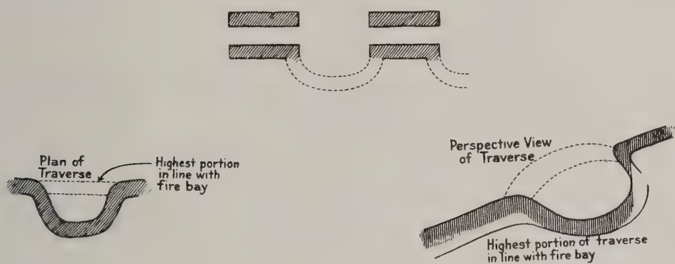
In regard to the traverses, the length must be sufficient to screen the full width of the trench with about 2 feet to spare. It can be made anything from 5 feet to 10 feet in width, but, in my opinion, *narrow and more frequent traverses are more valuable than less frequent wider ones.* The traverses are not to be built up, but are formed by leaving tongues of ground untouched between small sections of trenches. These small sections of trenches should be constructed first, especially when the enemy are momentarily expected; a temporary traverse is thus created by the untouched portions of the ground between the sections, these sections should be ultimately united, leaving the tongues of ground in between as a traverse, as shown on the diagram.

In constructing the traverse, the portion opposite the channel of the fire trench should be about 1 foot to 2 feet higher than the parapet. This gives additional protection from enfilade fire. Care should, however, be taken that the top of the traverses should emerge imperceptibly with the

parapet, *so that this rise is not conspicuous as an artificial one.* A very frequent mistake in constructing the traverse is to raise the back portion (instead of the front) in such a way that the back of the traverse shows up not only from the flanks but sometimes even from the front. Not only does this lessen the concealment, but is not so valuable from the point of view of protection as raising *the front* of the traverse in the manner which I have described.

With regard to the shape of the traverse, it should be rounded so as to give it a natural appearance even from the air, and also enable men to pass round it much more readily.

It has frequently been objected that a rounded traverse would not stop the blast of a high-explosive shell so readily as one with square corners. I do not think there is much, if anything, in this objection. The gases evolved in an explosion are so much lighter than air that their natural tendency is to burst upwards, and a rounded traverse will in all probability assist the explosive gases to move upwards quicker than a square one. If the gases, on the contrary, were heavier than air, there might be something in this objection. The effect of a high-explosive shell is to make



a great big hole in the ground, but a man lying down, even in the immediate neighborhood of the explosion is comparatively safe.

TO SUMMARIZE.

The following dimensions of a fire trench give a good working standard:

Depth, 4′ 6″ to 5′;
Parapet height, 1′;
From the top of the parapet to top of the firing step, 4′ 6″;
Width of the firing step, 1′;
Width of the bottom of the trench, not including the firing step, 1′ 3″ to 1′ 6″;
Width from top of the parapet to the top of parados, 3′ 3″ to 3′ 6″;
Width of parapet on the top to the front slope, not less than 4′ 6″, preferably 6′;
Parados, same height as the parapet, or 9″ to 1′ higher;
Width at the top of parados, 18″;
Length of the trenches between traverses, 20′ to 25′;

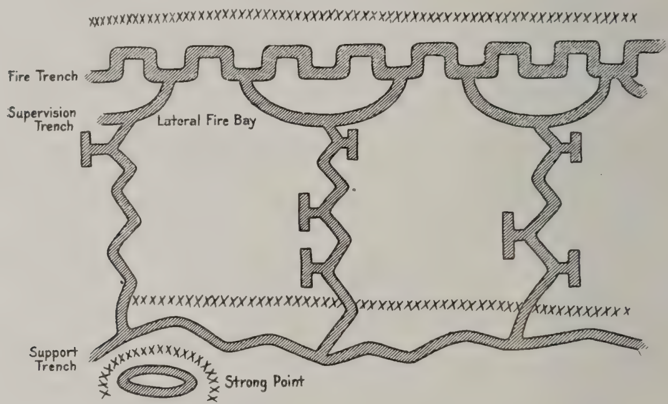
Traverses not less than 6′ back from the inner side of the parapet, say 6′ to 8′;

Width of the traverse, 4′ 6″, at least;

Dugouts on the rear side of the trench under the parados, or leading from communication trenches.

INSPECTION, COMMUNICATION, SUPPORT TRENCHES, ETC.

The following diagram is an example of a type of fire trench with inspection, communication and support trenches:



The object of the supervision, or, as it is sometimes called, lateral communication trench, is for the purpose not only of assisting in the supervision of the men in the trench, but also in accelerating reliefs, especially in a fire trench which is of such a narrow type that there is some difficulty in men passing each other. The supervision trench in its simplest form is made in loops from one portion of the fire trench to the other. The necessity for traverses is thus done away with. It may be made wide enough to allow a stretcher to be taken along it, but, as a general rule, is narrow—about 2′ 6″. It is usually placed immediately behind the parados. If a fire trench is captured by the enemy, it can be used for bombing them out. It will be noticed in the diagram that the support trenches have been placed about 80 yards behind the fire trench, the result of experience shows that this is about the best distance, but this, of course, depends upon circumstances. One would naturally place the support trench in a dip in the ground, if this dip were anywhere within reasonable distance of the fire trench. It is usually considered a mistake to construct the support trench a short distance, say 20 or 30 yards, from the fire trench, as overshots from artillery aimed at the fire trench are then extremely likely to hit it. The support trenches should also be provided with firing steps, so that in the event of the fire trench being captured, it can be utilized as a fire trench, and it is also of advantage to be able to command the back of the fire trench with your fire from the support trench. The support trenches can be made of the "Key" type, with recesses.

OBSTACLES.

The main object of obstacles is to delay the enemy while under the close fire of the defenders. With this object in view, there should be arranged:

(1) To break up the unity of action and cohesion of the attacking troops;

(2) They should tend to deflect the parties thus isolated into the best swept fields of fire;

(3) They should finally arrest the attackers under the close fire of the defenders. They should therefore fulfil the following conditions—

(*a*) They should be under the close fire of the defenders. As a general rule, they should be placed just over 40 yards from the parapet of the fire trench, so as to prevent the enemy throwing hand grenades over them into the fire trench. Their position, however, depends on circumstances, such as the opportunity of making use of a stream, hedge, ditch, or fold in the ground for the purpose of hiding or increasing the value of the obstacle.

It is impossible to exaggerate the importance of having every portion of the obstacle under the close fire of the defenders, and if for any reason, such as a dip in the ground, the obstacle is not under the fire of the defenders from the immediate front, every effort should be made to site the trenches in such a way that it is covered from the flanks.

They should, of course, not afford cover to the enemy; they should therefore be placed, if possible, in a fold of the ground, as shown in the diagram, in such a way that they are concealed from the enemy, but are under the close fire of the defenders. The following position for an obstacle is right:

This position is entirely wrong—

(*b*) They should be difficult to remove or surmount, and will be most effective if special appliances not usually carried by

troops have to be used for their removal. It is particularly important that they should be anchored securely.

(*c*) They should not be liable to damage by the artillery fire of the enemy.

(*d*) They should be concealed. Concealment is clearly of the utmost importance, not only as visible entanglements betray the existence of an otherwise well concealed trench, but, if concealed, they are obviously much less likely to be damaged by the artillery fire of the enemy, and the enemy are also unable to estimate the damage done to these, and may attack prematurely in consequence.

(*e*) They should force the enemy to adopt an upright position in attempting to surmount them. It is evident that a man is much easier to hit standing up than when lying down.

(*f*) They should be arranged so as not to impede counter-attacks.

(*g*) The obstacle *should not be liable to damage by the rifle or machine gun fire of the defenders.*

(*h*) The obstacle should be strongest at those points which are under the least effective fire control of the defenders. This, of course, has the result of sweeping the attacking force into positions which are best covered by the defenders' fire.

(*i*) They should not of necessity be continuous, but may be constructed in sections. *Occasional gaps in the line will often lead the attackers to crowd in towards them.* Such passages may be provided with land mines, and should also be covered by rifle and machine gun fire.

The form of obstacles most frequently used are firstly an abatis. An abatis is formed by limbs of trees firmly picketed down with the branches pointed and turned towards the enemy, strands of barbed wire interlaced between the branches adds further to their efficiency. The construction of an abatis can seldom be attempted unless suitable material is on the spot, but it is a very valuable form of obstacle in the neighborhood of woods, bushes, jungle, etc.

WIRE OBSTACLES.

The two forms of wire entanglements most frequently used are high wire entanglements and low wire entanglements. High wire entanglements form a very effective obstacle, and is exceedingly difficult to surmount. Its disadvantages are that it is much *less readily concealed* than low wire entanglement, it is *more easily shelled* by artillery fire in consequence, and is *much more easily damaged* by artillery fire, the stout posts used are blown away in great big chunks and drag portions of barbed wire with them. *The effect of artillery fire on them can also be more easily estimated.* Another disadvantage of high barbed wire entanglement is that they are *very easily damaged by the defenders' rifle and machine gun fire*, for, as a general rule, they are higher than the parapet of the trench. The consequence is that high entanglements frequently necessitate sending out men at night to repair them, and the defenders have a considerable number of casualties in consequence.

Low barbed wire entanglements do not form such an effective obstacle, and are more easily surmounted by the enemy, but they have other advantages, which, to a certain extent, make up for this. A very much greater width of low barbed wire entanglement can be constructed with the same amount of wire. They are much more easily concealed, they are not so easily destroyed by artillery fire, and they are not so readily damaged by the fire of the defenders. It is also necessary for the attackers to adopt an upright position in attempting to surmount them. Before the present war, the objection used against low barbed wire entanglements was that they were very easily surmounted by means of ladders or carpets carried by the defenders, but in actual practice this is not such a very great objection as might appear. The men with ladders, having something heavy to carry, are the last to arrive on the scene, and, in all probability, will arrive too late.

Before the present war, no engineer would suggest the use of a low entanglement; but, since the present war, low barbed wire entanglements have become increasingly popular; not only are they *much more readily concealed and much less easily damaged by the fire of the enemy, but are also much less readily damaged by the fire of the defenders.*

CONCEALMENT OF OBSTACLES.

It always seems an extraordinary thing that galvanized barbed wire is used for entanglements; it would be just as cheap and much more effective to use wire of a less conspicuous nature. Barbed wire was originally used in agriculture, and was galvanized not only to prevent it rusting but also to make it visible that cattle would not come in contact with it. For military purposes, we wish to use it from an entirely opposite point of view, and yet we continue to use the same material. It could be very easily made less conspicuous by coloring it with some neutral tint.

For the attachment of barbed wire, we also use large pit props, which are exceedingly visible. In wooded country there is a reason for this, as the wood can be obtained on the spot, but in most portions of our line in France and Flanders and the coast, the wood props have to be carried from the railhead, and *bayonet pointed steel rods* would be equally easily obtainable and would not be any more expensive. They also take less space and can be more easily carried up to the trenches. Bayonet-pointed steel rods have other advantages, they would make the obstacle much more effective, and they can be much much readily concealed. In section the rods can be made oval, and they can be painted with *daubs of the primary colors,* red, green and blue, with occasional splashes of white to break up the dark appearance of the shadow on the lower portions. When these steel rods are colored in this way, they are almost completely invisible *50 or 100 yards off.*

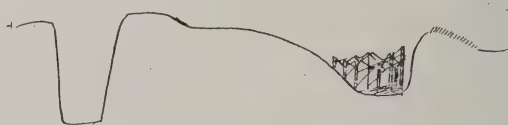
If a little ingenuity is shown, it is extremely easy to conceal obstacles in other ways. One very rarely comes across a piece of ground in which there is not some existing feature which can be utilized for this purpose, such as a river, stream, ditch, row of trees, hedge, or fold in the ground. If there is no existing feature available, as a last resource you can always make an obstacle appear as if it were an old standing fence extending across the ground. In utilizing a hedge for the purpose of

augmenting or hiding your obstacle, it is necessary to obtain a field of fire through it. It should therefore be partially destroyed, and should be cut down in such a way that it looks as if it were an old broken down hedge. It is not a very difficult matter to give a hedge an appearance of this kind if a little common sense is used in doing it. The stumps should be soiled with earth, so that the white newly cut portions are not conspicuous.

There are many other existing features that can be used for hiding obstacles, such as sunken roads, railway cuttings, etc., and as Flanders is a hop-growing country, hop poles may be used for this purpose, planting them in such a way that the enemy are deceived as to the real object of their use.

A natural fold in the ground, as in the diagram, may also be used.

and, if no such fold is available, *an artificial pit can be usually created with very much less labor than is necessary for constructing a trench.* This can be done as follows:



If pressed for time, it is only necessary to replace the sods along line *A-B*.

In pasture land the sods would, of course, have to be removed and then replaced. In ploughed land, all that is necessary is to scrape some of the top soil to one side and replace it afterwards. The same principles should be borne in mind as in constructing trenches. The rise in the ground viewed from the side of the enemy should be indistinguishable from a natural contour, and in fact the ground should appear as if it had not been disturbed.

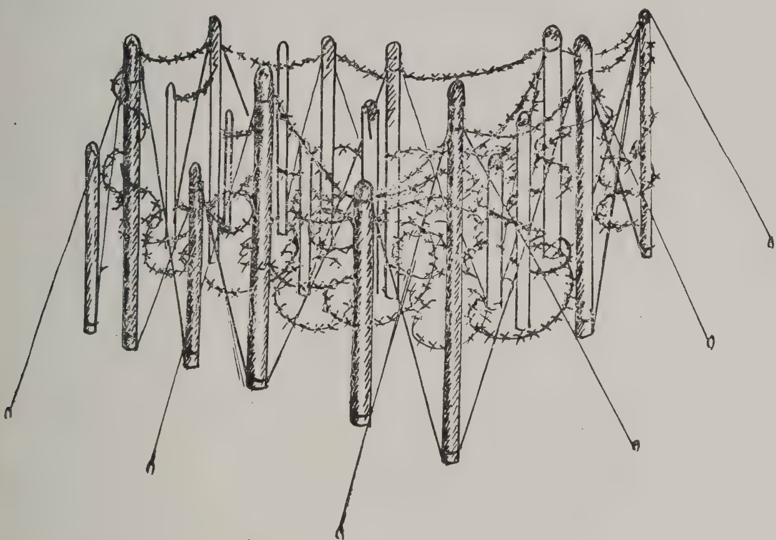
Care should be taken not to provide cover for the enemy behind the excavated earth.

The ordinary high parapet wire entanglement is constructed as follows: Posts 5 to 6 feet in length, and 4 or 5 inches in diameter are usually used and so as to render the passage of the obstacle by means of hurdles, planks, etc., more difficult, the posts should be driven into the ground at irregular intervals (of 5 to 6 feet) and at varying heights 3 to 6 feet. Each post should be joined with tightly strung plain wire, the head of one to the foot of the next and so on. The wire should be wound round the post and secured by staples. Barbed wire should then be hung in loose coils between posts. The *looser the coils,* the better. The coils should

be hung in such a way that it is impossible to crawl under without the use of cutting tools.

LOW BARBED WIRE ENTANGLEMENTS.

Low barbed wire entanglement is usually made by driving pickets into the ground, so as to leave 12 or 18 inches projecting. The top of these pickets are then joined to one another with wire. A much better form of



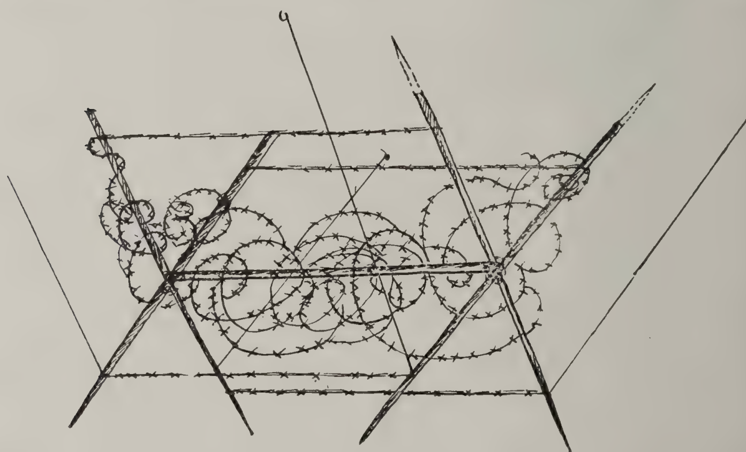
low wire entanglement is made by arranging the coils of barbed wire in loops as in the diagram. A complete circle is first made with the aid of plain wire, and then continuous loops are formed as illustrated. They should be picketed down in places.

Another useful form of barbed wire entanglement is the "gooseberry" or sphere of barbed wire; it is very easily constructed and can be made in the trench and thrown out at night. They are made as in the diagram with circles of barbed wire interlaced as shown. As a rule a piece of loose barbed wire is left hanging on, which may be attached to a picket.

These form very good obstacles, especially for blocking up a communication trench or a sap.

When trenches are near together, as they are in Flanders, it is important that the obstacle should be of such a nature that they can be easily put up at night, and for this reason obstacles have been constructed which can be thrown out or pushed out with large poles at any time. The spheres of barbed wire described above are very useful for this purpose. Other forms of obstacles are the knife rest obstacles which consist of a framework constructed in the form of a knife rest, as shown in the diagram, with barbed wire attached to each portion of the framework.

These knife rest obstacles always lie upright whatever position they may fall, and the consequence is that, whatever their position, they remain effective obstacles; they should be anchored down firmly and the adjoining knife rest obstacles should be connected with strands of barbed



wire, or they should be placed so as to break joint. Up to the present they have been made with a framework of wood, but it is more satisfactory in every way to *construct the framework* of bayonet pointed steel rods as suggested previously in the case of high wire entanglements. These obstacles consist of bayonet pointed steel rods, and can be constructed so that they fold up, and are thus more easily carried down a narrow trench. They are unfolded and clamped, and the barbed wire attached before they are thrown out of the trench.

The Germans use iron rods which screw into the ground like a corkscrew. They are less conspicuous than wood, and can be put up noiselessly at night.

Another form of obstacle which is being used considerably in France is one consisting of French steel wire; this consists of a continuous spiral of plain wire 3′ 6″ in diameter, each turn of wire being clipped to the turns on both sides in five places. It is, however, not barbed in any way, and can be made into a much more effective obstacle by interspersing loops of barbed wire among it, and also by attaching numerous fish-hooks

to it. One can quite imagine that if a considerable number of fish-hooks are attached to it, it would be an extremely difficult matter to get through it.

COAST DEFENCES.

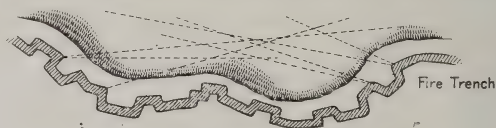
In considering the question of coast defences, it is necessary to bear in mind the principles which were laid down in the first lecture, and also to consider what is likely to happen in the case of an invasion. An invading force would, of course, land under the cover and protection of the guns of an enemy's fleet, and there can be no possible doubt of this, that the enemy's fleet would take considerable risks and come in as close to the land as possible, as happened when we landed troops in the Dardenelles. Naval guns send projectiles of *low trajectory*. Howitzer shells are not, as a rule, fired from ships; the consequence is that when the ships bombard the cliffs, the shells would hit the cliffs and bring large portions down. Shells that failed to hit the cliffs and sailed over, would probably not land until they had gone some hundreds of yards inland. The consequence is that trenches sited *10 to 20 yards back* from the cliff edge would in all probability be perfectly safe, except from shrapnel, and, if constructed with a vertical face *at the top,* would be quite safe even from shrapnel, if the men were crouching down at the bottom of a trench. Trenches in this position would be quite safe from the bombardment of the cliffs by the enemy's guns. As, although the enemy's artillery fire will bring down large portions of the cliff, the *portions of the cliff removed would not extend more than 30 feet back.* These trenches, although giving adequate protection to the men would, owing to the *absence of field of fire,* be valueless in attempting to repel an invasion. It is therefore necessary to construct fire trenches on the *very edge* of a cliff, so that they will be able to command the whole of the beach, including the dead ground at the bottom of the cliffs.

If one imagines what is likely to happen in the case of an invasion, the enemy will, in all probability, land from armored boats with a machine gun in the bow of each. The enemy's fleet coming close in, would bombard the cliffs until their troops were actually on the shore, and, until the bombardment stopped, it would be impossible to fire at them. *It is therefore necessary to have fire trenches at the very edge of the cliff and support trenches 10 to 20 yards back, with frequent communications running up to the fire trenches.* A few sentries should be placed in the fire trenches and will give warning of the landing, and immediately the bombardment has ceased the defenders would rush up from the support to the fire trenches, or what remained of them, after they had been shelled by the enemy.

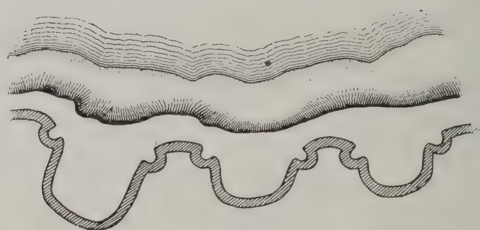
As I stated before, it is most important that these fire trenches *should command the whole of the beach.* The enemy would naturally expect that the ground at the base of the cliff would be the least likely to be commanded by the fire of the defenders, and in consequence would make a rush for this dead ground, which they would think would be comparatively safe. Precisely the same thing happened at No. 1 Cape Helles landing at the Dardenelles; those of our troops who were fortunate enough to land on the beach at all, made a rush for the base of the cliff where they remained comparatively safe until nightfall.

Now there is a certain amount of difficulty in commanding the dead ground at the bottom of a cliff; this can be done in three ways—by bringing oblique fire to bear on it, by making the parapet of the trench so thin that the defenders are able to lean over the cover of it by these means or by bombing.

In most parts of our coast, the edge of the cliff does not run in a dead straight line; there are all sorts of little bays and inlets, and it is comparatively easy to arrange the fire trenches so as to cover the whole of the beach by *oblique fire* as shown in the diagram. If, on the other hand, the cliffs run in an almost dead straight line and are very vertical, it is not such a big matter as might be supposed to shovel down portions of the cliffs so as to get oblique and grazing fire in this way. But, in addition to this it is sometimes necessary, in order to get a field of fire, to make the parapet of the trench so thin that in most soils it might be penetrated by a rifle bullet, so that it is of the utmost importance in coast defences that you should be well acquainted with your penetration table, so that you



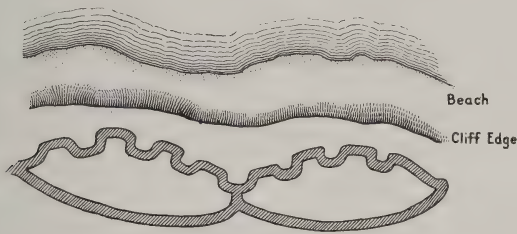
Oblique Fire Commanding Ground at Base of Cliffs.



know exactly when your parapet is likely to be bullet proof or not, and if not bullet proof you should proceed to make it so. The simplest method of doing this is to make a *groove* in the middle of your parapet, 6 inches wide, and of sufficient depth, say 1 foot or 2 feet, and fill this groove with *shingle* taken from the seashore. Sandbags full of shingle might also be used for this purpose. *The chief point to remember in coast defences is that it is of the utmost importance to get a field of fire on the whole of the beach;* it is of infinitely greater importance than ever concealment. I have travelled down the whole of the East Coast, and have rarely seen any trenches which were ideal from this point of view. The great majority of them were sited in such a position that the only thing defenders could fire at would have been ships out at sea. You cannot do any harm to battleships with rifle fire. There are other ways of getting over the difficulty of getting sufficient field of fire on the beach. One line of trenches might be sufficient if made in serpentine curves as shown in the diagram.

The defenders would occupy the loops at the back until the bombardment had ceased, and would then rush up to the forward loops or what

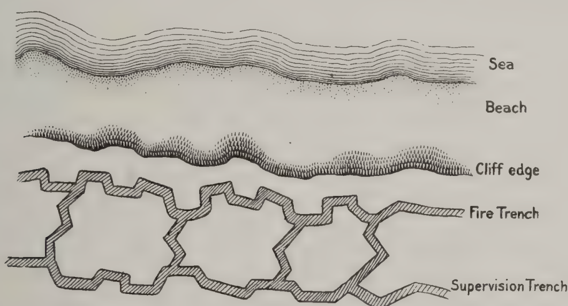
remained of them. A third way of bringing this about is to arrange trenches in a triangular manner, as shown in the following diagram:



The defenders would occupy the base of the triangle until the bombardment had stopped.

It has been suggested that one line of trenches should be constructed, and should be sited about 15 or 10 yards back and that when the bombardment has stopped the defenders climb out of these trenches and *line* the top of the cliff to repulse the attacking force. I think one would find in actual practice, especially if we had raw troops to deal with, that it would be *extremely difficult to get them to leave the cover of their trenches to line the top of the cliffs.*

It must be remembered that in all probability there will be only a few seconds to fire at the enemy as they are rushing up the shore, and it would be difficult to get the troops out of the trenches sufficiently quickly



after the bombardment has stopped, and if they lined the edge of the cliff before the bombardment had ceased, they would be extremely vulnerable to shrapnel.

TO SUMMARIZE.

The best way of arranging coast defences is to construct fire trenches on the edge of the cliff, bearing in mind the importance of field of fire to the dead ground at the bottom of the cliff, together with a second line of trenches from 10 to 20 yards further back, with frequent communications up to the fire trenches. It must be borne in mind that the troops in all probability will only occupy these trenches for a few hours. It is therefore unnecessary to make extremely elaborate trenches for the comfort of the men. On most of the coast an enormous amount of money

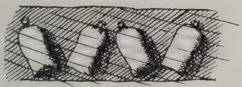
has been spent in erecting trenches with elaborate overhead cover, and so on, and in many cases the support trenches have been placed much too far back. It seems to me that it is of utmost importance that one should be able to get the men out of the support trenches into the fire trenches in the quickest possible time. Elaborate overhead cover in the support trenches is unnecessary. If the men are occupying them overnight, overhead cover does not give them any sense of additional security. It makes the trenches frightfully dark, and the men are continually colliding with each other and knocking their heads against the overhead cover. The support trenches should be narrow and deep, and in this way will be exceedingly well protected against shrapnel.

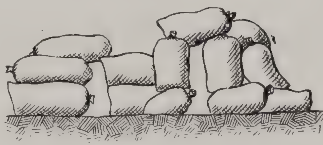
In regard to the fire trenches, from a point of view of safety: it is not so necessary to have the trenches as narrow as in ordinary land warfare when there is a chance of howitzer shells dropping into them. There is also not the same necessity for many traverses, except in any position where there is the smallest risk of the enemy bringing fire to bear along the length of the trench. If they follow the cliff edge in serpentine manner it is sometimes sufficient.

Narrow trenches are, however, an advantage if, as will in all probability happen, you have raw troops to deal with. *It is much more difficult for them to run away,* as it is obvious that in a very narrow trench where the men have difficulty in passing each other, that they would have to knock down every man between them and the next communication trench before they are able to sneak out of it. In regard to fire control, the support trench being so close up, would act as a supervision or lateral communication trench.

There are one or two points which must be taken into consideration. There is the question of the concealment of the trenches, and the question of the concealment of the men's heads. Concealment of the trenches is not of such great importance as is the case in deliberate entrenchment elsewhere. It would be extremely difficult in any case for ships out at sea to locate trenches on the cliff, but concealment of the trenches is of a certain amount of importance, as of course, *it is of great advantage if the men who have landed on the shore are not able to spot where they are being fired from.* The concealment of the trenches themselves is a very easy matter, and can be done if we keep the same principles in mind which we discussed in concealing trenches elsewhere.

Most of the soil taken out of the fire trenches can be put up behind in the form of a parados; the parados helps to hide the heads of the men as they appear on the top of the cliff. The parados should be made of such a shape that it appears to be a continuation of the face of the cliff. *Loopholes* should not be provided, as they restrict the field of fire, and in the few seconds available while the enemy are rushing up the beach, it is advisable to bring as many rifles and as rapid a fire to bear upon them as possible. Concealment of the men's heads, however, can be increased by making the top of the parapet irregular or if sandbags containing sand are used, *which is not altogether advisable* unless these sandbags are blinded with tufts of grass, they can be arranged in the following fashion:





The siting and construction of trenches on portions of the coast not consisting of cliffs, such as ground sloping gently to the sea or sand dunes, is a comparatively simple matter. Grazing and flanking fire are readily obtained and concealment is as a rule not difficult.

Many parts of the coast consist of sandy bays bordered on each side by rocky promontories. The sandy bays are usually the only possible places for landing; on the promontories a landing is as a general rule impossible.

The proper places for the strongest posts, such as machine gun entrenchments, are at the points marked in the diagram. These posi-

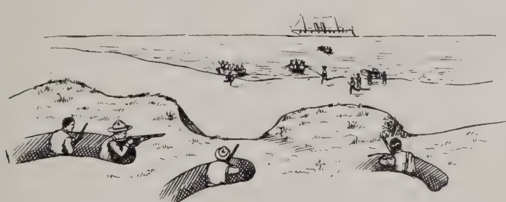
tions should be sited *as low down as possible,* and, if no natural inlet is in existence, one can readily be made as a sort of cave.

Strongposts in this position have the following advantages:

1. They are absolutely concealed;
2. They are exceedingly safe from shell fire;
3. They cannot be easily captured in reverse;
4. They can bring flanking and grazing fire on the whole of the beach.

During daylight, machine gun emplacements in these positions would usually be amply sufficient in themselves to stop a landing, and yet these are the positions which have been most neglected.

Among the sand dunes, flanking fire can frequently be brought to bear in this way.



The chief difficulty among sand dunes is to prevent the sand blowing and filling up the trenches. The tendency has been usually increased owing

to the sods having been stripped for rivetting purposes, and thus exposing acres of sand.

Sand blowing can be lessened—

1. By the use of canvas or brush-wood hurdles, placed in the little valleys up which the sand usually blows;
2. By covering the bottom of the trench with a smooth surface. Ration tins have been used for this purpose and it is surprising how readily the sand blows off them;
3. A *smooth* frame-work of canvas or cheaper material might be used to cover the whole of the trench; this will be much cheaper in the long run than continually cleaning the sand out of the trenches. The frame-work should be easily removable.

Note: The concealment of obstacles is an extremely simple matter, and can be easily obtained on the lines suggested in the previous lecture on Obstacles.

BREASTWORKS.

Breastworks were originated for the purpose of doing away with drainage difficulties, and may consist of a combination of the ordinary trench and breastwork, or, on the other hand, of a breastwork completely raised above the ground level. The advantages of breastworks are that you get rid of the problems of difficulty in drainage. They afford a large field of fire, and the high command on flat ground affords cover from view to the communication trenches, support trenches, etc., behind them. They also have an additional advantage in having a high command, that they are more easily adaptable to the use of loopholes than a trench of low command. The chief disadvantage is that they are in most cases extremely visible, and, in consequence, very readily shelled and destroyed by the enemy; they also entail a considerable amount of labor compared with the ordinary fire trench. In Flanders, they have usually been constructed with sandbags, and, up to the present time, in our line of sandbags of a light color.

It was pointed out in the winter of 1914-15 that sandbags of various colors would be a great advantage, not only for hiding loopholes, but even to a certain extent in making the breastwork itself less conspicuous. It was pointed out that the best colors to use are the three primary colors, red, green and blue, and, the more confused the appearance of these colors, the better; in fact, you simply want daubs of color without the smallest suspicion of regularity. The breastwork itself, on the principle that I mentioned before, that is, the reverse principle to what the artist does when he attempts to reproduce the appearance of a rise in the ground, should have a few *white sandbags at the base of the breastwork* in front. *This helps to hide the conspicuous shadow at the lower portion of the breastwork.*

Some months after it was suggested in this country, the Germans adopted colored sandbags. It may have been due to accident, as it is well known they are short of jute, and were using any worn-out clothing, etc., for the purpose of making sandbags, but, whether due to design or not, I am informed by everyone who has lived in trenches opposite them, that the results have been extremely efficacious. Officers, who have been out since the beginning of the war tell me that, in the first instance, the German breast-

works were extremely conspicuous and their loopholes were even more conspicuous. The change in the alteration of these breastworks by the use of colored sandbags was almost magical in its results. Loopholes which were previously extremely visible become concealed to such an extent that it was absolutely impossible to spot them with the aid of the finest field glasses. Not only that, but when, during one of my lectures, I suggested that the chief value of colored sandbags was for hiding loopholes, one of my hearers got up at the close of the lecture and stated that they were of the utmost value in making the breastworks themselves inconspicuous. He stated that the German lines were only 100 to 150 yards away from his battalion; their breastworks had been constructed with colored sandbags, and, in certain lights, they were completely invisible at even this short distance away.

Everyone who is in a position to know, at any rate the men who have lived in the trenches, are of precisely the same opinion; they all agree as to the great value of the German colored sandbags. The expense of coloring them will be extremely small; the worse the coloring is done, the better, and the greater the daub and confusion in the coloring the more valuable the breastwork is.

Before I discuss several types of breastwork, it may be advisable to inform you in detail the correct way of laying sandbags. Sandbags are issued in bales of 100 weighing 40 lbs.; they are 33″×14″ when empty, when full they are 20″×10″×5″, and when full a sandbag weighs 60 lbs. In using sandbags, they should be used three quarters full; they should be laid in alternate layers of stretchers and headers—a stretcher being a sandbag which is laid with its long face to the front—a header is a sandbag which has its end to the front. The thing to remember in laying sandbags is that the soil is liable to escape from the seams or the mouths or chokes of the sandbags. The consequence is that sandbags should be laid with the seams and chokes towards the interior of the breastwork, so that, if any soil escapes, it will escape into the interior of the breastworks and not where the men are standing.

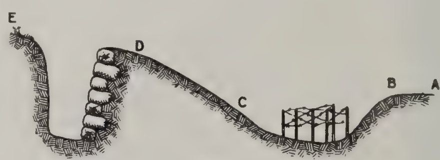
The sandbags should also be laid so as to break joint, that is, there should be no two vertical joints above each other.

A sandbag revetment will hold up a slope of 4 and, if the same principle be borne in mind which was mentioned in discussing natural slopes of earth, the revetments can be made even more vertical by making the lower three quarters of the slope 4, the upper quarter can then be made absolutely vertical, and this, of course, gives considerable additional protection from shrapnel, and I believe actually has the effect of enabling you to put the lower portion of the slope even more vertical than usual.

In laying sandbags, to get a slope of $\frac{4}{1}$ each sandbag should be laid at right angles to the slope; this necessitates making a bed for the first sandbag, thus—

In addition to a breastwork completely consisting of sandbags, a breastwork can be constructed of a much more effective type and with a considerable economy in sandbags. In the type of breastwork suggested, the face of the breastwork is revetted in the ordinary way with sandbags, simply using one layer of sandbags with alternate headers and stretchers, the soil utilized to form the breastwork is taken from the front and thrown up behind as in the diagram.

Land, in which it is necessary to make a breastwork, is, of course, waterlogged, and water will accumulate in the hole from which the soil is taken. It is therefore necessary to keep your pumps working to get rid of the water as it accumulates, but, after the digging is completed, the excavation should be filled with barbed wire obstacles, and the water accumulating in front not only hides the entanglement but also increases the value of the obstacles. A breastwork of this kind, if properly constructed, can be made so that the enemy's artillery observers would never dream that it is anything but a natural rise in the ground, and from this point of view is absolutely concealed.



A·B·C·D·E – A Continuous Natural Contour

It is, however, necessary to construct the breastwork with a very gradual slope and of an irregular natural appearance.

The excavation from which the soil is taken should be from 20 to 35 feet in front of the interior slope of the breastwork. This, of course, involves a certain amount of extra labor, but is well worth the trouble, as, if an effort is made to conceal it, *it also has the value of making it to a certain extent shellproof; as, of course, the thicker the parapet of the breastwork, the less likely will it be destroyed by the field artillery shells of the enemy.* A parapet may be 20 feet thick with advantage.

The average soldier in attempting to make a breastwork of this kind will construct it in absolutely geometrical straight lines and angles. The excavation in front would be in square or oblongs. This, of course, would have a hopelessly artificial appearance, and would give the show away at once. If the excavations are made of an irregular natural outline, and the breastwork has also a natural appearance, the whole thing will, in all probability, be mistaken for standing water with rising ground appearing out of it from the opposite side. The whole of the exterior, as well as the upper surface of the parapet, should be made as rugged and irregular as possible; this not only helps to hide the men firing over the parapet, but also enables loopholes to be hidden with the greatest ease, as the loopholes cannot be distinguished among the numerous depressions or projections.

ORGANIZATION OF WORKING PARTIES.

In deliberate entrenchment, except when making any but the smallest entrenchments, men are not kept continuously at work, but are changed at intervals. It is usually advised in the text books on military engineering to divide these periods into four hour reliefs; it is frequently considered that time is wasted in handing over the work from one party to another if a shorter time is taken. I find, however, that you get the best work out of the men if the reliefs are of a shorter period, even as little as half an hour; the organization should be good, and the reliefs should remove their coats while the previous party continue working up to the very last second, the relieving party should take their tools from them, and start working at once. In this way not more than a few seconds are wasted.

Rate of Excavation.

In ordinary soil an untrained soldier should excavate the following per hour: 1st hour, 30 cubic feet; 2nd hour, 25 cubic feet; 3rd hour, 15 cubic feet; 4th hour, 10 cubic feet; or, 80 cubic feet in a 4-hour relief.

These rates hold good for a maximum horizontal throw of 12 feet, combined with a lift out of a trench 4 feet deep.

Tools.

In moderately hard ground, a good proportion of tools is 110 shovels, 55 picks, and 10 crowbars per 100 men. The normal distance apart men are spaced for work is 2 paces; *i. e.*, 5 feet.

Task Work.

Task work is of value for the purpose of getting the most out of the men, but it has several disadvantages; it is unnecessary in the presence of the enemy, as every man will naturally work to the limit of his power. It tends to give trenches a rigid artificial appearance consisting of straight lines and angles, and, in most soils it is impossible to arrange tasks fairly. One man may have nice easy soil to dig in, his neighbor may have stones or rocks.

In arranging task work, the first relief should be larger than the succeeding ones, as the diggers have less distance to lift the excavated earth. It is suggested in the text books that each relief should leave the interior slope of the trench with a vertical face. This is a mistake unless plenty of revetting material is available, as no trench will remain standing with a vertical slope; *the interior should be sloped as described in previous lectures.* In commencing to dig, the diggers start on the left of the task and break in from the right.

Tracing.

Tracing may be done by spit-looking, but, in the case of fire trenches, a picket or stone should mark the firing point for each rifle.

Laying tapes is not advisable, as this has the tendency of giving trenches a regular, artificial appearance, owing to the straight lines and angles; in fact, it has the effect of giving the enemy a well defined target instead of an inconspicuous one.

Tool Depots.

Depots for materials should be formed as near as possible to each group of works. Before the arrival of working parties, the tools will be laid out in the tool depots in heaps about 10 paces apart, the men filing between the heaps and receiving the tools as they pass. The picks should be carried in the left hand, the shovel in the right.

Drill.

There are various forms of drill used for starting the constructions of a trench. A common form of drill used is that described in a little book of "Grenadier," the drill is as follows:

(1) The section is filed in single rank facing the center of the position to be entrenched;
(2) Work of command "number";
(3) Tell off into 3 squads;
  1 to 5 right squad;
  5 to 10 center squad;
  11 to 15 left squad;
(4) To arms lengths outwards extend (word of command). This represents men with the inner arms touching the shoulder of the next man as in open interval drill.
(5) "Outer squads 2 paces forward—march" (word of command);
(6) "Center squad 2 paces step back—march" (word of command);
(7) "On the line of your toes—dig."

It is necessary if an attack is likely to take place that the rifles and accoutrements of all parties working in fire trenches must be within reach without necessitating the men leaving the cover of the trenches.

Night Digging.

In night digging, it is of the utmost importance that the greatest quietness should be observed. For this reason, men should be taught to pick up their tools and carry them without the least noise. The commander of each squad must see that the proper alignment is kept, and that there is a good field of fire in the immediate foreground of the trench. To make sure that this is so, the ground may be marked with white paper about 30 yards in front of the trench, or one of the men may be sent on in front with a small electric torch at his back. It seems to me that for night digging the simplest form of drill is the best. Men should follow the squad leader in single file. On arriving at the ground where the trench has to be constructed, the squad leader halts; the leading man touches him on the shoulder to indicate that he knows the exact position in which he has to commence to dig, and an N. C. O. see that he grounds his pick to the left of his task. The squad leader then takes another two paces forward, and is again touched on the shoulder by the second man, who stops and commences digging. The squad leader takes two more paces forward, and the third man touches his shoulder and so on, until the whole of the squad have got their right positions.

As quietness is of the utmost importance at night, it is much better to commence the men digging without any word of command at all; they should dig as quietly as possible and shovels should be used in preference to picks. Even on stony ground, it will usually be quite possible to dig the first foot or two with a shovel alone, and thus to obtain sufficient lying down cover if spotted by the enemy. There is quite a simple device which lessens the dangers and difficulties of digging at night, and which has been used in several places in France with a considerable amount of success, and this device is the *use of a screen;* the screen, of course, is not in any way bullet proof, but is simply intended to hide the movements of the men while digging. It should consist of *dark colored canvas* material as light in weight as possible, and should be hung up in front of the position between poles like a tennis net. It may be argued that the screen in itself would be visible and the enemy would turn a machine gun on to it. In actual practice this is not so, even on a bright moonlight night on the crest of a hill. *Just as a low-lying dark colored wall or evenly clipped hedge is strikingly inconspicuous at night, so is this screen.* A badly clipped hedge, isolated bushes or trees and particularly moving figures, are comparatively easily seen at night. There are certain precautions, however, that one should take in using this screen; the *ends* are somewhat liable to show up, and, if possible, the ends should be broken by hanging the screen between trees, bushes, hedges, walls, or even buildings, and if it is impossible to do this, the ends should be sloped gradually to meet the ground. Even if the enemy put up their flares, a screen of this kind simply looks a shadow on the ground.

Dug-outs.

The object of dug-outs is to provide shelter for the men from the effects of weather, etc., and also to provide protection from the effects of the enemy's artillery fire and grenades. It is a comparatively simple matter to obtain protection from shrapnel, bullets and splinters from burst shells and hand grenades, and, for this purpose, an overhead cover consisting of a few sheets of corrugated iron or a few stout flat planks with a thickness of 9 or 12 inches of earth is sufficient, but it is a very different matter constructing a dug-out so that it will be proof against the artillery projectiles of the enemy.

For protection against the artillery projectiles, the following amount of protection is necessary:

Field Gun Shells.

For shells of 3-inch calibre, 4 feet of earth with a top layer of heavy stones or bricks to cause an early burst give a fair amount of protection.

Howitzer Shells.

Howitzer shells up to 6 inches, *7 feet of earth on 12-inch logs laid side by side with a top layer of boulders or concrete give good protection.* Against howitzers, larger than 6 inches, thickness up to 16 or 20 feet of earth, or 10 feet of cement concrete reinforced with steel is necessary.

It is of the utmost importance that dug-outs should be well con-

structed. A badly constructed dug-out is frequently a source of danger. The concussion of a high explosive shell dropping in the neighborhood of the dug-out is sufficient to bring down the roof and bury all the men inside it. This is so much so that the old soldier frequently rushes out of a dug-out when trenches are being bombarded with heavy shells, and seeks protection in a deep narrow trench; the young soldier, on the contrary, frequently rushes for the protection of a badly constructed dug-out, and is buried underneath in consequence.

Situation of Dug-outs.

In the early part of the war dug-outs were frequently constructed under the parapet of the fire trench; this was done with the view of having the men close at hand in case of an attack, but it was found to have many disadvantages. They were very vulnerable in this position and very unsafe in consequence, and also there was a certain amount of difficulty in arranging the fire step so that men were able to fire over them easily. Latterly there has been an increasing tendency to put the dug-outs further and further back. They should, however, be scattered about as much as possible and not constructed all in the same place. Some of them may be made in the neighborhood of the lateral communication trench, or off the ordinary communication trenches. The majority of them should be constructed in the neighborhood of the support trenches. Shelters should be small and sufficiently numerous to provide cover for each rifleman, they should be easy to get in and out of quickly, and, as a rule, should have *two entrances* in case one of them is blocked up by the artillery fire of the enemy. The entrance to them should not be exposed to direct fire, and should always communicate with some point of value. The materials of which the roof is formed must be strong enough to carry whatever weight is to be placed upon them; they should be well drained.

The opening of dug-outs should usually be concealed, so as to prevent the enemy throwing bombs into them if they temporarily get possession of the trenches.

They should be sited and constructed in such a way that they will be of assistance in repelling the enemy who enter our trenches.

A movable wire door should be placed across the entrance, so as to prevent the enemy throwing bombs in, and yet allow the defenders to fire through it.

One exit may be arranged to lead into a concealed bombers' lair, or a small fire bay constructed to fire laterally over the open ground between the communication trenches.

Revetments.

The term "revetment" is applied to any artificial material, used for retaining earth at a steeper slope than that which it would naturally assume. The materials generally used are sods, sandbags, gabions, fascines, hurdles, or continuous hurdle work, willesden canvas, planks, expanded metal, etc. In revetting a trench it is advisable to bear in mind the kind of slope which stops up for centuries in nature, such as the bank of a stream, the slope of a sand dune, or an old disused quarry, and it will be noticed that a slope of this kind slopes considerably at the

bottom for the lower two-thirds or three-quarters, whereas the upper portion of the slope is vertical or even overhangs, as shown in the diagram.

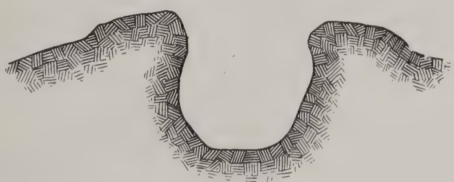
The important thing to remember is that the lower three-quarters of the slope should slope considerably. The upper portion may be made more vertical, and this will give greater protection from shrapnel. Sods are useful in cases where no other revetting material is obtainable, and is particularly valuable among sand dunes. The sods should be cut 18 inches long, 9 inches broad and 4½ inches thick, and should be laid with a slope of $\frac{3}{1}$ and in alternate layers of stretchers and headers with the grass upwards.

Sandbags.

Sandbags used for revetment should be built up in English or Flemish bond, and should be laid as described in the lecture on breastworks.

Hurdles.

Are placed touching each other along the line of revetment to be executed, pickets are driven into the ground so that the hurdle inclines towards the parapet at a slightly gentler slope $(\frac{3}{1})$ than that at which



it is required to stand. Unless anchored securely the revetment will not stand. Logs or fascines with wires attached are buried in the parapet as it is being made, or, in the case of an existing parapet, are sunk into holes dug for the purpose.

Willesden canvas also makes a useful revetment. Stout pickets should be driven in from about 1½ feet apart and anchored securely. The canvas is stretched between these and the parapet, being laced with a wire to the top and bottom of every 4th or 5th picket, that is to say, at about 6-foot intervals.

Wire Netting.

Wire netting can be used in soils which are not too sandy; it is held by pickets passed in and out of the meshes driven into the ground and anchored.

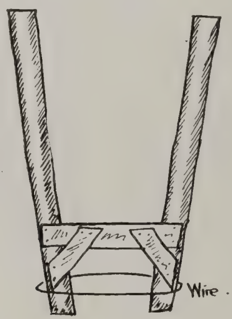
Gabions.

Gabions are cylinders open at both ends which, when standing on one end and filled with earth, make a strong revetment. The usual dimensions are 2 feet exterior diameter and 2′ 9″ in length. They may be made of almost any material capable of being bent or woven into a cylindrical form, such as brushwood, Willesden canvas, wire netting, Gabian steel, etc., they are useful in making breastworks.

It does not need much ingenuity to suggest other forms of revetments, for instance, in constructing a simple fire trench in heavy clay, the clods

of clay placed by hand as one would place bricks, are useful for revetting up the top of the interior slope of the parapet as vertically as possible. The water soon oozes out of these clods of clay, and they remain hard and firm even in wet weather. These clods of clay are often very useful in constructing trenches among the sand dunes if a layer of clay can be discovered under the sand, as frequently happens. One of the most useful forms of revetment which has been used considerably in Flanders recently is that known as the "U" Frame.

In this revetment, the long pickets are joined together about 2 feet from the bottom by timber, and below this there is a strand of wire netting, uniting the lower ends of the pickets. This helps to prevent the upper end of the pickets springing upwards. Planks are placed across the adjoining cross pieces of timber, so that the men can walk along these planks. Any water that accumulates in the trench will, of course, do so below the planks.



Repair of Trenches.

It is of the utmost importance that men be detailed constantly to keep trenches in a good state of repair and continually drained. Trenches fall in owing to water accumulating in them, and owing to the interior slope not having been constructed properly. The bottom of the interior slope is frequently made too vertical or even undercut; it is the lower portion of the slope that should slope considerably. The interior slope, in fact, should have a tendency to be somewhat concave and not in any way convex. It is particularly important that trenches should be repaired at once when they show any signs of falling in. This particularly applies during wet weather. Men should be sent out in the middle of the rain to see that the drainage system is working properly. What usually happens is that a small portion of the trench falls in, blocks up the drain, water accumulates behind this, and causes more of the trench to fall in, until what, in the first instance, would only take a few seconds to repair, will ultimately give rise to a considerable amount of labor lasting for days. It is of the utmost importance therefore that immediately any heavy rain appears, a few men be sent out to keep the drainage system all right, and this will prevent a considerable amount of labor afterwards.

Loopholes.

There are three typical arrangements of single loopholes:

Type A. Gives the next field of view, but is most difficult to conceal because of the wide opening in front;
Type B. Is easier to conceal as it has a small opening in front;
Type C. Is a compromise between *A* and *B*, but can be adapted to give a large field of fire.

The important thing to remember in all these types of loopholes is that they should be bullet-proof at the angles.

Another type of loopholes is the continuous one.

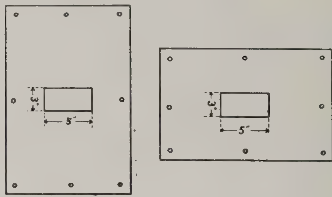
The framework of the loopholes can be made with the aid of a box or by sandbags. The angles should be rounded off so as to enable them to be made bullet-proof, with shingles or some other good bullet-proof material. In Flanders loopholes are not generally used, except for sniping. The continuous horizontal slit is extremely visible, and, for that reason, it is an easy matter for the enemy to fix their machine guns in such a way that they can traverse it from end to end. It is also found that it is not advisable to allow men to fire through the ordinary loophole when repulsing an attack of the enemy. The men are so inclined to simply put their rifle round the corner and fire through the loophole without looking along the line of sight. For this reason, men have now been ordered to fire over the top of the parapet when repulsing an attack of the enemy.

Concealment of Loopholes.

As pointed out in my lecture on breastworks, in the case of sandbag breastworks, it is much easier to hide loopholes if the sandbags are of different colors. Loopholes are much more easily concealed if they are sited obliquely, and also if the exterior of the parapet is made as irregular and rugged as possible. A loophole plate can be easily concealed in a sandbag breastowrk by making holes round the edge of the plate, so as to facilitate the attachment of portions of sandbags stuffed with straw, and in this way to give the plate the same appearance as the rest of the breastwork.

Loopholes may be blinded by means of a lid. The exterior of the lid should, of course, be made to resemble the outside of the parapet of the trench. If the parapet is grass, the sods should be secured to the exterior of the plate; if it is earth, the plate should be covered over with mud, and, if consisting of sandbags, the sandbags should be secured to the exterior. The lid should be hinged above and can be made to open by means of a wire running through rings along the roof of the loophole. In addition to this, a piece of sacking should be used to blind the back of the loophole, and prevent a light showing through when the lid is raised. When firing through the loophole, the lid should be raised very carefully, so that the movement will not be seen by the enemy. A cap may then be placed in the loophole; if not spotted by the enemy in about a minute, it is usually safe to fire through it.

Steel loophole plates are frequently used to fire through, usually of the following dimensions:



The best way to work then is to use two, one fixed in front of the loophole, and the other made to slide in a groove behind. The rifle is then placed through both loopholes and fired. Steel plates used in this way are extremely safe, as it would be most unlikely for one of the enemy's bullets to penetrate the loopholes of both plates.

Machine Gun Emplacements.

Siting. Machine gun emplacements should be constructed on several alternative sites, they should, of course, be concealed, and they should be sited so as to get oblique fire. When they were first constructed in Flanders, they were usually made in a slight salient projection from a straight line of trenches, and were very easily seen in consequence. The enemy, therefore, before an attack always invariably destroyed our machine gun emplacements during a preliminary bombardment. If the general line of our trenches is made in an irregular series of salients and re-entrants, it is much easier to hide our machine gun emplacements. They can frequently be far up in a re-entrant where they are least likely to be discovered, and sited in such a way that they bring oblique fire to bear across the front of the salients.

A Vickers maxim on a tripod requires a platform of earth measuring about 4 feet square, and sunk about 12 to 18 inches. On the right hand side and in rear of the platform a trench 2 feet wide may be conveniently cut to a level 3 feet below that of the platform, and leading from there to the main trench.

QUESTIONS ASKED AFTER LECTURES.

Query. You speak of concealing parapets in a turnip field. If you knew the average soldier you would realize that all the turnips would be removed from your parapet during the night.

Answer. This is absolutely a question of the right kind of discipline. If the British soldier were only treated as an intelligent human being, and the reason for doing these things explained to him, difficulties of this nature would not arise.

Q. The position of most trenches would be given away by the men throwing ration tins, etc., out of them.

A. This is entirely a question of the right kind of discipline.

Q. How do you manage to get the replaced sods to retain their color during a hot summer?

A. By cutting the sods fully six inches thick in hot weather. If the

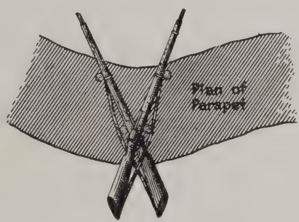
trenches are occupied, the parapet can be watered if water is obtainable; another alternative is to sow some quickly growing seed, such as a mixture of rye grass and mustard and cress. A mixture of this kind comes up green in about the time the grass of the sods begins to wither, viz., in about 3 days. A third alternative is to give the foreground the same appearance as the withered grass of the parapet by sprinkling it with a weak acid of a 5 per cent solution of copper sulphate.

Q. Does not sowing the parapet with mustard and cress appear to be somewhat absurb and hardly practicable?

A. It has already been done by the Germans, and Mr. Martin Sutton, of Sutton & Co., also informs me that he has sent seed for this purpose to our own troops in France.

Q. In advocating a wavy parapet to help to hide men's heads, I assume you mean an embrasure.

A. The old type of embrasure consisted of straight lines and angles, and would simply provide the enemy with a mark to fix their rifles on. This is precisely the sort of thing that must be avoided. The waves should



be made of a natural appearance, so that they are not in way conspicuous to the enemy.

Q. You advocate that trenches should be sited in waggly lines in all sorts of salients and re-entrants; would not this make it extremely likely for our men (especially at night) to fire into part of their own lines?

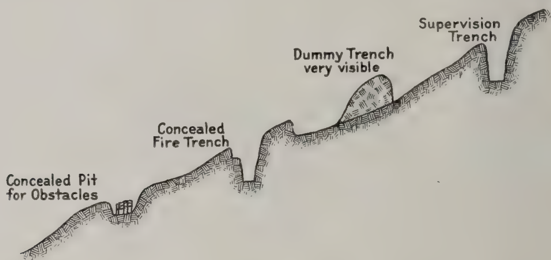
A. I might agree with you that this is a likely thing to happen unless proper precautions are taken, and, even under present circumstances, I hear frequent complaints of our line being fired on from portions of our own firing trenches some hundred yards away. It is an easy matter to take safeguards against this happening. When reliefs are occupying a trench at night for the first time, they even have only a hazy idea of what is their own front, and I see no reason at all why the position for each rifle should not be marked on the parapet of the trench in some simple manner, such as by placing 4 pegs in the position shown in the diagram, so as to limit the traversing of the rifle to either flank, in such a way that there is no danger of firing on our own portion of the line.

Q. Do you not think that if men are encouraged to conceal their heads, it will have a detrimental effect on their shooting? Is it not customary at the present time to order men to expose themselves boldly over the parapet while repulsing an attack?

A. On the contrary, if men feel they cannot be seen, they will expose themselves much more boldly and will fire with much greater confidence and with greater accuracy. The reason men have been instructed to expose themselves boldly over the parapet is to avoid them attempting to repulse an attack through loopholes, as, not only would they have a restricted field of fire, but are extremely likely to keep their heads behind cover, and fire through the loopholes without looking along the sights.

Q. I can see the value of concealment for the individual sniper, but you suggest the whole of a battalion should be concealed in firing over a parapet; this would not be of any advantage, as you could not put the enemy out of their reckoning by more than a few inches, and the enemy firing at the top of the parapet would be just as likely to hit the men they could not see as if they were visible.

A. If trenches are, as I suggest, constructed as irregularly as possible, the enemy cannot locate the top of the parapet. I find in all my demonstrations in getting men to attempt to fix rifles on positions where they think they have located a man's head, they almost invariably fix their rifles not



a few inches, but usually yards, away from the target they are expecting to fire at. If it is an easy matter at such a short distance as 40 yards to deceive men as to the position of the top of the parapet in a single fire trench, how much easier will it be in France where there are usually several lines of trenches, and, possibly dummy trenches in addition. In the above diagram, how easy will it be to make the enemy think the top of the dummy parapet is the real fire trench?

Q. How can you conceal in chalk?

A. Concealment in chalk is an exceedingly easy matter, owing to the fact that dummy trenches can be made so readily. In almost the whole of the line in France, there is a foot or two dark colored soil on the top of the chalk. The exposed chalk should be covered with this. Existing trenches can be easily made very inconspicuous by accumulating the top soil in the trenches during the day and shovelling it out at night. Dummies can be readily constructed by banking up the chalk as much as possible, and using the dark upper soil to put into the interior of the dummy trench, so as to increase the shadow effect as viewed from aeroplanes. There can be no possible excuse for making a well defined visible target, as we do in France to-day.

Q. Do you think that concealment is unwise because a great big hefty parapet and high conspicuous obstacles give the troops a feeling of greater security?

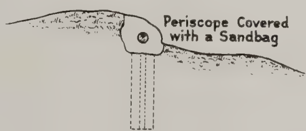
A. The feeling, if it exists, is an illusory one. The lessons of the war have proved conclusively that a ditch dug by an agricultural laborer (owing to the fact that it is less conspicuous) is of greater military value than many a fortress.

Q. How do you conceal a rifle?

A. If the rifle is held flat on the upper surface of the parapet, it not only enables you to take a steadier aim, but it is also extremely difficult to see, as only the round orifice of the muzzle could be detected with powerful glasses. To get an extreme degree of concealment, the muzzle may be covered with grass on a grass parapet, or a dark colored veil on a mud parapet, care, of course, being taken not to hide the sight.

Q. Would not the first shot give the position away?

A. With smokeless powder it only gives the approximate position. Concealment up to the time the first shot is fired is an enormous advantage, and, in the case of snipers, is all that is necessary, for, as a general rule, he would choose some other position when he wished to fire again.



Q. How can you hide a periscope?

A. In the same way as a man's head. Cover the periscope with a sandbag smeared with the mud of the parapet and stuff with grass so as to give it a rounded outline, and make a small loophole for the mirror. The periscope should lean up against one of the protections of the parapet in such a way that the enemy get the impression that it is part of the rise.

Q. The sun shining on the glass would give the position of the periscope away.

A. It is an easy matter to safeguard against this; no periscope should ever be visible to an enemy 40 yards away.

Q. Do the same principles apply in concealing big guns?

A. Exactly. If it is an easy matter to conceal a man with a rifle 20 yards away, it should be equally easy to conceal a big gun at 200 yards, even from the air.

Q. Dummy trenches, owing to the absence of shadow, can be distinguished from real ones by aeroplanes?

A. Not if well made. The light colored subsoil should be banked up considerably and the sides to look like a conspicuous parapet and parados, and the dark colored upper soil should be used to cover the interior so as to increase the shadow effect.

Q. Would not an irregular parapet make a man more likely to be hit when passing one of the depressions?

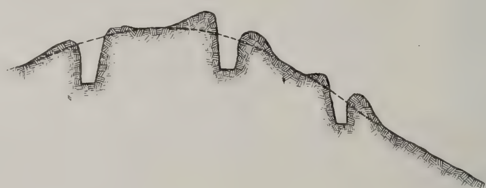
A. Men are not normally walking along the firing steps, but at a considerably lower level on the grid below it. It should be made clear that the bottom of each depression is the safety level, and that men should not expose their heads above this level except when observing or firing. If these simple precautions are taken, the trench is then much safer than the ordinary parapet, as if a man accidentally exposes his head above the safety limit, it is much less likely to be seen by the enemy.

Q. What should be the height of the lowest part of the depression?

A. 4′ 6″. From the fire step.

Q. Will not this limit the number of men that can be put into each fire bay?

A. For an emergency, some sandbags could be kept handy to place on the fire step, so that the men can fire over the rises as well as along the depressions, but, in these days of machine guns and obstacles, it is hardly conceivable that it should ever be necessary to man a trench to its fullest extent.



Q. Irregularity will make the parapet not bullet proof?

A. Not necessarily. The rises should be made bullet proof, but, even if they were not so, it would be much safer to fire over an irregular parapet than a flat-topped one.

Q. Will not the men's heads be conspicuous from aeroplanes?

A. No, and even if any of the enemy's machine gunners and riflemen had an aeroplane photograph by their sides, it is not going to help them much in spotting the men who are firing over the opposing parapet.

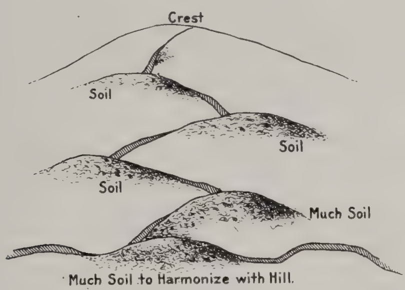
Q. How would you conceal trenches on a hill?

A. On the forward slope, the soil should be utilized to block out the view of the excavation. On the crest of the hill, the soil should be placed behind so that the parados will form a false crest. On the reverse slope soil should be placed both in front and in the rear in such a way that it looks like a natural contour.

Q. How do you conceal communication trenches on a hillside?

A. Communication trenches running up a slope can be concealed with the greatest ease; the background helps enormously if the trenches are

properly constructed, the soil should all be utilized to block out the view of the interior of the trench, thus:



Q. Will not an excavation full of stakes, barbed wire, etc., in front of a breastwork interfere with a counter-attack?

A. Not to any greater extent than existing obstacles. Wire entanglements are cut through the night before an attack. A moat in front of a breastwork can be bridged across the previous night, or, when it is being constructed, oblique passages can be left, and each passage should be covered by a machine gun.

Q. Is it advisable to make a parados not bullet-proof on a salient?

A. No.

Q. Where do you suggest dummy parapets should be placed?

A. Behind, and if possible at a higher level than the existing parapet. Troops always have a tendency to fire too high, and if you give them a conspicuous target at a higher level, the parapet will rarely be hit even by a very bad shot.

Q. Are not most of your suggestions in notes for Infantry Officers on Trench Warfare?

A. Most of the important points were mentioned by me 12 or 18 months previous to the publication of the pamphlet referred to. For example, at an early part of the war, I bombarded the authorities with memoranda, diagraphs and photographs illustrating the importance of the irregular parapet (I have photographs in my possession of trenches made in 1914 illustrating this principle, and constructed in an irregular series of salients and re-entrants). Little if any notice was taken of these ideas; finally in desperation I published an article on the subject, this article, I hear, was reproduced and extensively discussed in America, shortly afterwards (whether a coincident or not, I do not know) the Germans adopted an irregular parapet.

Q. You may hide a particular trench, but is it possible to hide a system of lines of trenches?

A. I take it, the meaning is that if you have several miles of trenches, the fact that one portion is discovered will give the whole position away.

This is correct if trenches extended continuously in straight lines over

miles of country, but is not so if made in irregular curves or in sections with dummy trenches between the sections.

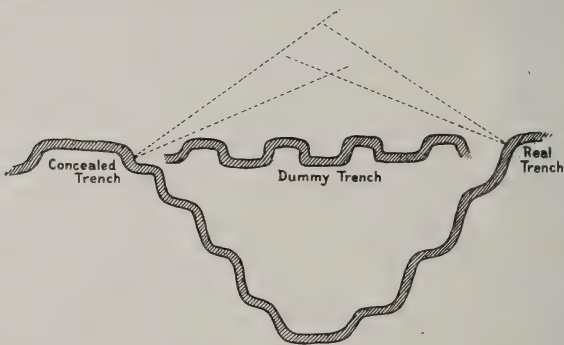
If the trenches are well concealed and dummies well made, the dummies will in all probability be shelled and the trenches escape, when the enemy attack the intact trenches, it will come as an unpleasant surprise to them.

Q. What is the connection between the construction of trenches and golf courses?

A. In golf course construction not only do similar drainage revetting problems, construction of breastworks, etc., come in, but also an eye for country, imitating and making the best use of natural features, and a similar trend of thought in devising traps for the enemy.

Q. Must we not as a rule choose between command and visibility or concealment and limited field of FIRE?

A. It is agreed that in certain cases command (*e. g.,* a breastwork) makes concealment more difficult, but even then is in no way impossible,



in other cases (*e. g.,* the front of a hill) owing to the excellent background, concealment is exceedingly easy.

One of the points I have tried to make clear, time after time, in these lectures is that it is not at all necessary to sacrifice field of fire for concealment.

Q. If crops are replaced on the parapet of a trench the men will not be able to see?

A. It is surely not suggested that replacing turnips, cabbages, potatoes, etc., on a parapet which has a good field of fire will seriously limit that field.

Q. If you are firing to meet an attack, the value of concealment is not great. In other cases rifle fire is from loopholes.

A. When the enemy are attacking a concealed position and fire is suddenly opened against them some of them may lie down; these men will not be idle, but will probably be attempting to fire at the defenders, and surely it is an advantage to the defenders if the attackers have a bad target and the defenders a good one.

The fact also that the defenders know they are not seen and do not present a good target to the enemy is sufficient to increase their confidence

in repulsing an attack and they will fire with much greater accuracy in consequence. Even under present conditions in France, there are almost invariably a certain number of the attackers dropping down (possibly with machine guns) into shell holes, and firing at any heads they see exposed over the opposing parapet; it is clearly of importance to give them a bad target instead of a good one.

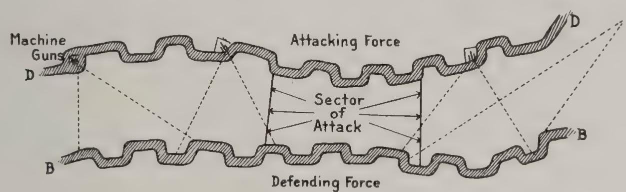
In many cases the enemy while attacking over a small sector sweep the parapet of contiguous trenches with their machine guns, so as to prevent the defenders in these trenches firing at the attacking force from the flanks.

Trenches *B. B.* swept by machine gun fire from *D. D.* during the attack.

I have been informed by more than one officer that while occupying the flanks of a sector that was being attacked, the machine gun fire on their parapet was so severe that they were unable to expose a head without having a bullet through it.

Surely if this can be prevented by confusing the enemy as to the exact position of your parapet it is of considerable value.

When altering the parados of a captured trench which is being consolidated, it is of the utmost importance to convert it in such a way that



not a single man can be seen observing over it. The enemy might even imagine it had been evacuated and refrain from shelling it in consequence.

The dangers of sniping from loopholes is that an intelligent enemy can always discover in time the exact position of a loophole by the simple method of taking the angles and would fix a rifle on it. The advantage of making every yard of your parapet of such a nature that you can snipe from anywhere without being seen, is that the enemy never have a defined spot to fix a rifle on.

Q. Has not one generally to dig where the enemy's fire will permit?

A. It is sometimes advisable to sacrifice a few acres of ground for the purpose of getting a commanding position and its attendant advantages.

Q. With reference to your remarks on page 19, how would the rear-guard escape?

A. Why should they escape? It is surely occasionally advisable to leave small concealed strong-posts of 20 men or so with machine guns in the region of railways, roads, etc., with instructions that they must hold out to the last with no thought of retirement.

Q. How do you get over barrage fire?

A. Artillery fire sprinkled promiscuously behind your lines is not so likely to damage your important points as fire aimed deliberately.

Q. Do not artillery fire largely by maps?

A. True: but even assuming (which I do not agree) that it is impossible to confuse the enemy as to the position of the important points on the map which your troops are occupying, it is clearly of advantage to hide them from artillery observers on the ground.

Q. Is there not a danger, when altering existing trenches at night so as to make the parapets irregular, that the field of fire to the immediate foreground will be diminished?

A. This may be safeguarded against by placing small pieces of paper or electric torches (shaded towards the enemy) on the ground in front of the trench, and thus make certain that every man is able to cover the bottom of the wire with his rifle fire.

Q. Are the principles propounded in your lectures of any value in the attack?

A. Of the greatest possible value. I do not see how an attack can be really successful (as measured in the only common-sense way, that is, as a balance between profit and loss) unless the possibilities of the enemy's defence and the best and quickest method of consolidating them when captured have been previously studied.

We might consider the advantage of a study of concealment, enfilade fire, traps and consolidation of captured trenches during an attack.

CONCEALMENT.

Unless we fully understand the principles of concealment it is impossible to concentrate and hide the guns, trench mortars, men, etc., assembled and obtain the element of surprise so necessary in every successful attack.

It is also impossible to hide the guns pushed forward during an attack to support the infantry. One of the reasons the battle of Loos was a failure was owing to the fact that most of the guns pushed forward during the attack were wiped out owing to their emplacement being so badly hidden.

Unless the possibilities of concealment are fully understood, it is extremely unlikely that all the enemy's obtsacles, gun emplacements, etc., will be discovered.

ENFILADE FIRE.

The importance of enfilade fire must be fully understood, not only in attacking but also to counteract similar measures taken by the enemy.

TRAPS.

It is clear that attacking troops are much less likely to fall into traps made by the enemy if they have previously been made acquainted with them.

CONSOLIDATION OF CAPTURED TRENCHES.

The capture of a system of hostile trenches is usually considered an easy matter compared with the difficulties of retaining it, but if the principles discussed in these lectures be fully understood it should be an easy matter to retain any captured trenches.

Of especial importance is the rapidity of conversion, concealment an enfilade fire obtained in converting the enemy's parados into an irregular parapet, and also the construction of strong posts in positions unlikely to be shelled before a counter-attack, by joining up shell holes in an irregular manner so that the ground appears undisturbed when viewed from above.

CONCLUSIONS.

Entrenchment siting and making is entirely a question of common sense.

Cunning should be part of the training of the regular soldier. It is neglected, as it is looked upon as cowardly and un-British. Cunning in warfare simply means attempting to inflict a maximum amount of damage to the enemy with the minimum to ourselves.

If the principles discussed in these lectures are fully grasped, it is an easy matter to alter existing trenches to conform to them.

There is a tremendous lot of unnecessary labor not only at home but in France, owing to the fact that we have not yet understood the fundamental principles of entrenchment-making.

There is little continuity of policy in our present lines in France. Battalions relieve each other at frequent intervals, and almost invariably scrap or leave unfinished work that has previously been done, and commence new work after their own ideas.

A little thought would frequently save an enormous lot of labor.

As an example of this, at one part of the line we took over from the French, we were narrowing the fire trench from 6 feet (or even 8 feet in places) down to 3 feet. We were doing this by means of sandbags, and we were carrying the sandbags full of soil from two or three hundred yards behind up to the fire trenches. What could have been simpler than to have made a fresh line of fire trenches, three or four yards behind the present one and used the existing trenches as an impassable moat (full of stakes, barbed wire and drainage water) in front of the new position? The whole thing could have been done with a tenth of the labor and cost of material and would have been much more effective when completed.

On part of the East Coast where the existing trenches on the cliffs had, at any rate, a good field of fire on to the beach, the battalions were given instructions to widen the parapets up to 12 feet and make them absolutely horizontal. It is clear that horizontal parapets 12 feet thick on the top of the cliffs would only be of value for firing at aeroplanes—needless to say, all these trenches have to be re-altered again to their original form.

If a little common sense is used, existing trenches in France can be easily made to conform to the foregoing principles. It is an easy matter to make the top of the parapet irregular, and constructed so as to get oblique fire for the individual rifles and machine guns.

It involves very little labor to make our fire trenches less conspicuous. If our trenches in Flanders were deliberately constructed to give the enemy as good a target as possible they could hardly have been made more visible than they are at present. What could be simpler than to accumulate the top soil or sods in the trenches during the day and shovel it out at night?

It is just as easy to make a parapet rugged, irregular and natural-looking as to flatten it out with a spirit level.

There should be no great difficulty in devising all sorts of traps for the enemy. Concealed bombing pits do not involve much labor. Straight stretches of our communication trenches can be readily loopholed for rifles or machine guns; obstacles can be easily hidden in pits, and many other traps can be equally easily constructed.

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Alphabetical List of Advertisers

Wm. E. Merrill

William E. Merrill.

BY

MARGARET E. MERRILL.

William E. Merrill, Lieutenant Colonel, Corps of Engineers, Brevet Colonel, U. S. A., was born at Fort Howard, Wisconsin, October 11, 1837.

His father, Capt. Moses E. Merrill, a graduate of the Military Academy, class of 1826, was killed at Molino del Rey on September 8, 1847. His mother, Louisa Slaughter, was a member of the old Virginia family of that name.

His ancestors on both sides fought for the cause of American independence during the Revolution. His early education was received at Louisville, Ky., and Cleveland, O. From 1848 to 1850 he attended Kingsley's School near West Point, and from 1850 to 1854 he was a student at St. James College near Hagerstown, Md., graduating in 1854. Reporting at West Point as a Cadet in June, 1854, he very soon took the position which he never lost at the head of his class. Familiarly known in the class as ''Padre'' Merrill, the name clung to him during his life. During his first class year he acted as Assistant Professor of Spanish. He was Class President and First Captain of the Corps of Cadets.

His career at the Academy and in the Army was marked by consistent and conscientious devotion to duty, which, while unobtrusive in its character, never left any one in doubt that duty would be performed regardless of all personal considerations, or like his gallant father, by the sacrifice of his life if his country's interest demanded it.

He was imbued with a deep religious sentiment, which was thoroughly consistent with the pure life he led from boyhood to the hour of his death. On graduating in 1859, he was appointed a Brevet Second Lieutenant in the Corps of Engineers, and Second Lieutenant, February 20, 1861.

In regard to his Civil War services space permits of only brief

reference. On September 12, 1861, he was captured by the enemy and remained a prisoner of war, being confined in a Richmond tobacco warehouse owned by Liggin & Co., southwest corner 25th and Main Streets, until exchanged, February 23, 1862. During his captivity he maintained that same indomitable spirit which made him equal to any situation in which fate might place him. His chivalrous feeling prompted him to join with John Markoe, Charles J. Pearson, George B. Perry, J. Harris Hooper, J. E. Green, and Charles M. Hooper in an offer to take the place as hostages of Colonel Corcoran, Colonel Milton Coggswell, Colonel Raymond Lee and others who were ordered by the Confederate War Department

> to be confined in a cell appropriate to convicted felons, to be treated in all respects as such convicts, and to be held for execution in the same manner as may be adopted by the enemy for the execution of the prisoner of war Smith, recently condemned to death in Philadelphia.

This offer was refused, but the petition which accompanied it no doubt led to action in their case, which resulted in their release from prison and their being returned to the tobacco warehouse.

In July, 1864, he was appointed Colonel of the First Regiment of U. S. Veteran Volunteer Engineers, which he commanded until it was mustered out of service in September, 1865. This regiment was employed in constructing block-houses and defensive works on the lines of the military railroads in Tennessee, Northern Alabama and Georgia. As Chief Engineer he designed and caused to be built throughout the Department of the Cumberland 160 block-houses, defending every railroad bridge in the department from the Kentucky State line to Atlanta.

General Sherman, in his memoirs, states:

> All the important bridges were likewise protected by good block-houses, admirably constructed and capable of a strong defence against cavalry or infantry, and at nearly all the regular railroad stations we had smaller detachments intrenched.
>
> In the protection of a bridge one or two log block-houses two stories high, with a piece of ordnance and a small infantry guard, usually sufficed.
>
> The only block-house that was actually captured on the main line was the one described near Allatoona.

He also caused the construction of a special canvas ponton train of a new design, which train accompanied the army from Chattanooga to Washington.

General Sherman also refers to this in his memoirs in the following words:

On the whole I would prefer the skeleton frame and canvas cover to any style of pontoon I have ever seen.

He also organized a complete map-making establishment at Chattanooga, equipped with printing and lithographic presses. Every officer of rank in the army that made the Campaign of Northern Georgia had a copy of the official map.

For his services in the war Colonel Merrill received the brevet of Captain, April 16, 1862, for gallant and meritorious conduct in an engagement with the enemy before Yorktown, Va.; that of Major, May 19, 1863, for faithful and meritorious services in the battle of Chickamauga, Ga.; Lieutenant Colonel, March 13, 1865, for faithful and meritorious services in the battles of Lookout Mountain and Missionary Ridge, Tenn.; and that of Colonel, March 13, 1865, for faithful and meritorious services in the battle of Resaca and New Hope Church, Ga. After the war he served two years on the staff of General Sherman in St. Louis and one year on the staff of General Sheridan in Chicago.

In 1870 Colonel Merrill was assigned to the charge of the improvement of the Ohio River, to which were added subsequently nearly all the tributaries of that river, on which duty he remained until the day of his death. He designed and built the great movable dam across the Ohio River, 5 miles below Pittsburgh, known as the "Davis Island Dam." This dam at the time of its construction was the largest movable dam in the world, and the lock attached to it the largest lock in area, being 600 feet in the clear in length, and 110 feet in the clear in width, with a capacity of one towboat, ten coal barges and two fuel flats. He also built two fixed dams with locks on the Monongahela River, and wholly or in part ten locks on the Muskingum River.

He served on a large number of Engineer Boards, especially on bridge boards and was the author of "The Ohio River Bridge Law," and had a principal part in the framing of "The Bridge Laws of the Great Kanawha and Muskingum Rivers." He was twice sent to Europe by the Government, the last time in 1889 as representative at the International Congress for the Utilization of Water. He was also the author of the present system of lighting western rivers, and of the Act of Congress authorizing it. He was the author of a work entitled, "Iron Truss Bridges for Railroads," 1870, "Improvement of Non-Tidal Rivers," 1885, and "Inland Navigation in France and the United States," 1890.

In January, 1873, Colonel Merrill married Miss Margaret E.

Spencer, daughter of the late Dr. John C. Spencer, of Cincinnati, O., formerly Surgeon, U. S. Navy. Ten children resulted from this union. Of these, two, Col. Thomas E. Merrill, Field Artillery, and Capt. Walter W. Merrill, Coast Artillery Corps, are officers of the U. S. Army.*

The military order of the Loyal Legion Commandery of the State of Ohio under date of February 20, 1892, published the following tribute to Col. William E. Merrill, their late companion. After reciting his services in detail it concludes:

Modesty was one of his most striking characteristics. A companion intimately associated with him during the Georgia campaign of 1864, when he was the constant recipient of such praise from his superior officers as was calculated to turn the head of a much older man, relates that he never heard Colonel Merrill refer in any way to any of his exploits. He was an accomplished linguist, a man of varied reading with a highly cultivated taste for art. His moral and social traits were no less admirable. Loyalty, integrity, a recognition of the rights of others, were his controlling motives. His manners were courteous, cheerful and marked by a vein of bright and kindly humor. He was a zealous and active member of his church (St. Paul's, Newport, Ky.), having been a member of the vestry for many years. He was a genial friend and companion, a model domestic character—a courtly, Christian gentleman and soldier. A more perfectly rounded and well balanced character is rarely seen.

A classmate in writing of Colonel Merrill said:

When, at West Point, he and a few others of his class were appointed a committee to adopt a device and motto for their class ring, and they selected for the first the Latin quotation, "*ad utrumque paratus in utroque fidelis,*" with an olive branch and sword, the emblems of peace and war, they did not then realize how completely it would apply to Merrill. He certainly did his part in both to the utmost of his power.

*[Died December 14, 1891, on a railway train en route from Cincinnati, O., to Shawneetown, Ill., while on official business. "Cullum's Biographical Register," Supplement, Vol. IV.—Ed.]

Military Roads on the Island of Oahu.

BY

Lieut. WILLIAM E. R. COVELL,
Corps of Engineers.

The island of Oahu, in the Hawaiian group, is small, having an area of only 600 square miles (equal to a square 24 miles on a side); it is isolated, being an island; its defense is of the greatest importance, due to its strategic position and the location of the important naval station at Pearl Harbor; and, finally, the construction of a complete system of military roads is quite feasible, both from an engineering and from a financial view-point, and very advisable from a military one.

In view of these facts it is hoped that a short discussion on military road systems and their application to this island may prove of interest and perhaps of a little value.

PHYSICAL REQUIREMENTS.

The physical make-up of a system of military roads must meet certain special requirements. A military road is built in time of peace for use in case of hostilities. When, therefore, the emergency comes, the road must be ready. No matter how long the road has stood up under the peace traffic, no matter how much good it has done for the community, its net return on the investment, from a purely military point of view, is naught if it is out of commission when the occasion for its military use arises. Hence the system must be as nearly permanent as possible. It should be built so that few repairs will be needed,—and so that the necessary repairs may be made quickly. Its surface should be passable in all kinds of weather, for the enemy might not pick out perfect days for its attack. It should allow the maximum speed of the military vehicles intended to be used upon it to be developed without harm to itself, or danger to the vehicles. The details of construction, such as widths, grades, curves, surface, etc., should likewise be determined with reference to the military vehicles intended to be used on it.

CIVILIAN VEHICLES.

The civilian traffic over any military road built on Oahu must be given careful consideration. Though in case of hostilities this traffic might be barred from military highways, in time of peace it would not be advisable and perhaps would be impossible to keep civilian traffic off the military roads. As in the case of the Army, the civilian horse-drawn transportation is entirely local. About 80 per cent of the horse-drawn trucks and drays never leave the limits of the city of Honolulu, while the remaining 20 per cent is used almost entirely within the several plantations.

A very large amount of freight is moved by auto trucks on this island, especially in the Kaneohe Bay region which no railroad reaches. Small freight is even moved commercially by auto trucks between Schofield Barracks, Waipahu and Honolulu in competition with direct railroad connections between these points.

Thus any extensive road system on this island should be built primarily for gasoline-propelled vehicles. It will be subject to very heavy traffic immediately upon its completion, which traffic will be liable to a very sudden and rapid expansion due to the impetus given by an abundance of good roads. That this is a very important question is shown by the utter failure of the territorial roads and city streets, many miles of which were built just before the automobile industry took on its present importance, to stand up under the present heavy traffic.

RAINS.

The heavy rains to which the island of Oahu is subject are as potent as heavy traffic in destroying roads. Though the climate of this island is unusually mild, the obstacles in the way of road building are the torrential rains. These, liable almost any time, are more frequent in the winter months. The precipitation averaged 75.23 inches in 1916, 63.38 inches in 1915 and 58.68 inches in 1914. The bridges, culverts and drains must be built to withstand the heaviest rains. As an example of what these rains may be, the precipitation of the recent storm of March, 1917, was 13 inches in twenty-four hours, in Honolulu and vicinity. In this storm, the rain finding weak spots in the roads and streets which had been caused by heavy traffic and only partly repaired, quickly made great gulches in the paving. The illustrations show some results of this storm. The two illustrations (page 647) of the concrete roads show that these were not affected by the downpour.

The small maps following show the distribution of precipitation

Liliha Street, Honolulu, after the storm. Road was in bad repair before storm.

Another view of Liliha Street.

and temperature. Careful consideration should be given to maps similar to these in order to economize labor and materials in areas not subject to heavy rains. The local branch of the Weather Bureau of the U. S. Department of Agriculture has very complete climatological data, back to and including the year 1905.

GULCHES.

Other grave problems are presented by the numerous gulches which cut deep into the island, especially those in the central plateau. The present roads in crossing some of these have sharp

Asphalt and macadam road after storm. Part of belt road around Island of Oahu.

and dangerous curves. In a system of military roads money and care should be freely spent to avoid these objectionable features.

SOIL.

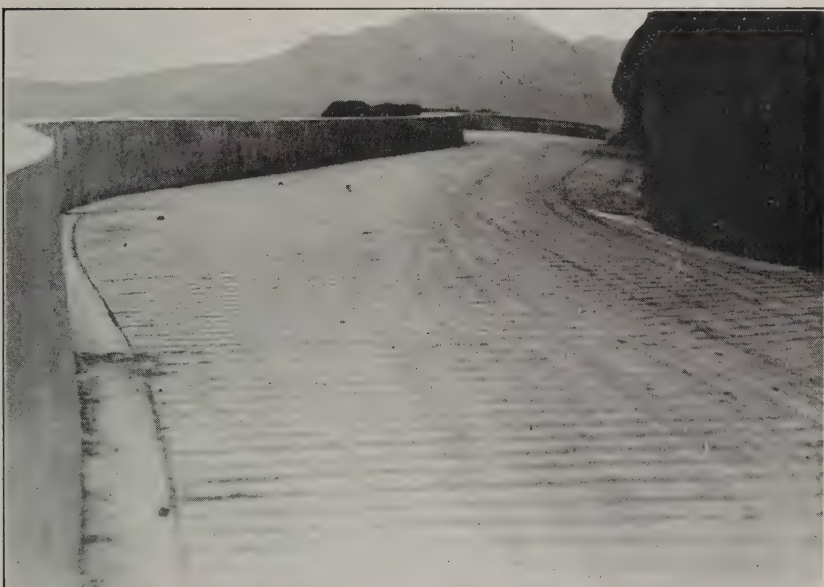
The soil of the island is all of volcanic origin, and is divided into three classes:[1]

1st. Sedimentary;
2nd. Yellow and Light Red;
3rd. Dark Red.

The first of these is found on the levels and flats bordering the sea.

[1] "Lavas and Soils of the Hawaiian Islands," by Walter Maxwell.

New city street, in outskirts. After storm.



Portion of belt road, recently constructed, on Nuuanu Pali. After storm.

It is similar to the common soil in the United States and presents no difficulties. The second is found in higher altitudes and less frequently. The third is the soil in which most of the sugar cane is grown. It covers the central plateau and the areas immediately above the sedimentary flats and lowlands.

Though the island is not subject to frosts, this soil exhibits a somewhat similar phenomenon due to moisture. In the basement of the College of Hawaii building, the concrete floor has bulged upward nearly a foot, with no apparent settling of the walls. A similar, though much smaller, action has been noticed in the concrete floor of one of the recently built batteries. This bulging is probably caused by an expansion due to the absorption of water, aided by the pressure of the side walls.

LABOR.

The labor problem for an undertaking of this size will be a grave one on this island. The local supply of citizen labor is limited, while it is probable that plenty of alien labor can be obtained without importation. If permission could be obtained for its use, alien labor on road construction could be used to great advantage, being both cheaper and more abundant, for certainly no military secrets would be exposed in mere road building.

As the city and county of Honolulu is compelled by law to employ only citizen, or eligible to become citizen, labor, the following quotation from the biennial report of the City and County Engineer on this subject is apt:

> The supply of citizen or eligible to become citizen labor, on this island, is limited. This is shown by the present scarcity and the poor quality of some of the labor employed on improvement work now under way. The maximum limit of the cost of public work which may be carried out in one year will not exceed $1,000,000.00 without the importation of labor. With work going on along other lines, such as, additions to the water and sewer system, harbor improvement, etc., the limit for road work will hardly exceed $500,000.00 per year. It would be unwise in my opinion to consider the importation of labor for road construction on this island.

MATERIAL.

Plenty of suitable sand and rock are available on the island. Cement and oil, if used, would necessarily be shipped from San Francisco. The sand and rock can be bought at standard prices, but on all other material shipped from the States, a high freight

Mean annual temperature and total precipitation, 1916.

Mean annual temperature and total precipitation, 1915.

Mean annual temperature and total precipitation, 1914.

Temperature curves are shown in *red.*

Precipitation curves are shown in *blue.*

rate would have to be paid, unless the shipping was done in Government vessels.

EQUIPMENT.

The necessary equipment too, if purchased in large quantities, would be shipped here.

In preparing the subgrade of many roads built in the Territory, excellent results have been obtained by the use of a sort of construction truck and roller, having 10-inch front and 20-inch rear steel wheels. As this seems to be especially fitted for use in this island and as the country shown is typical of that over which a large part of the military roads would be built, the illustrations (pages 651 and top of 653) are included:

EXPERIMENTAL ROADS.

The College of Hawaii built, over a year ago, several experimental stretches of road, comprising the following types of construction:[1]

(1) Asphalt macadam, using Union Oil Co. asphalt, a soft grade.
(2) Asphalt macadam, using "C" grade Standard Oil Co. asphalt.
(3) Coral.
(4) Warrenite.
(5) Reinforced concrete.
(6) Plain concrete.

Each of the asphalt macadam sections was divided into two subsections, one with and one without a seal coat of oil and fine rock. The road has been receiving traffic equal to the heavy traffic to be expected on the main military highways. After a year of use several results are apparent. Reinforcement in the concrete has clearly demonstrated its advantage, especially on an adobe foundation. The plain concrete had developed large cracks, possibly due to an upward pressure of the soil as mentioned above. The coral section is rapidly deteriorating, the Warrenite has developed bumps, while the macadam without the seal coat is raveling under the heavy traffic as shown in the illustration (bottom of page 653). The same type of road with the seal coat is in good condition, demonstrating the value of such a coat especially in a section subject to heavy rains, as this.

ROADS IN USE.

Somewhat similar results have been obtained from the roads in

[1]Report of Board of Regents, for 1917.

Subgrade finished. No special rolling except that by truck in delivering rock.

Subgrade partially rolled by truck in delivering rock.

use over the island. The mileage of these roads in the country districts are as follows:[1]

Country Districts.

Improved roads.	Belt roads.	Other roads.
	Miles.	*Miles.*
1. Asphalt macadam	15.50	2.8
2. Concrete	0.80	
3. Water-bound macadam	8.40	1.5
4. Coral	16.00	4.5
5. Gravel	5.60	
6. Oil macadam	16.10	
7. Earth	6.60	119.7
Totals	69.00	128.5
Unimproved roads	-----	42.5
Totals	69.00	171.0

The asphalt and oil macadam are kept in good condition only by constant repairs. They are very dangerous, however, in wet weather. The coral roads must be nearly remade after a torrential rain. The concrete roads, relatively new, have shown no wear as yet. Practically all of the main roads and streets now being built by the city and county of Honolulu are of this type. The water-bound macadam has been ruined by the heavy traffic of auto trucks.

It must not be assumed that these roads can be used, as they are, in the completed military system, for they are in a wretched condition, totally unfit for efficient use in military emergencies. For example, on page 654, are two illustrations of the Waimanalo dirt road after a rain. This road becomes impassable in wet weather.

The illustrations (pages 655 and 656) show the results of one storm on the coral road on the Nanakuli coast. This road is regularly washed out once or twice a year.

The Kaneohe Bay road is so bad that the City and County Engineer has constantly recommended its replacement by an entirely new reinforced concrete road.

KIND OF PAVEMENT RECOMMENDED.

We have considered so far the requirements of military roads in general. Dirt roads need not be considered—they are totally im-

[1]Report of City and County Engineers, Honolulu, 1917.

Right-of-way cleared of underbrush. Coral rock being dumped in place.

College of Hawaii. Experimental road. Section asphalt macadam, no seal coat. Taken March 10, 1917. Age of road, about one year.

Waimanalo dirt road after a rain.


Waimanalo dirt road after a rain.

practicable. Coral roads might be used for short distances in a few limited localities where the usual traffic would be light and the precipitation not too great. Ordinary macadam with no seal coat is not advisable, since that part of the pavement not ruined by the heavy auto trucks would eventually be torn up by the heavy rains. The various other forms of macadam with a seal coat are useful but also inadvisable for military roads on this island. Their durability cannot compare with that of reinforced concrete, while their slipperiness makes them very dangerous in wet weather. It is true that

their first cost is comparatively low, but this is counterbalanced by the longer life and fewer repairs of reinforced concrete roads.

The answer, then, seems clearly to be concrete, adequately reinforced with wire nets or similar material. This type of road not only meets the general requirements of durability, non-slipperiness and ease of traction, but also is practically the only road which will stand up under the destroying effects of the very heavy motor traffic of the island aided by the torrential rains.

These facts are established not only by theory but also by actual experience. The present reinforced concrete roads on this island have as yet shown no appreciable wear or deterioration, despite the fact that they have been built in localities subject both to particu-

larly heavy traffic and downpouring rains. The city and county of Honolulu have recognized this kind of pavement to be the best suited for their main streets and belt roads and are planning to lay it whenever possible from a financial standpoint.

COST.

The first cost of reinforced concrete with squeegee surface is approximately $1.80 per square yard, exclusive of grading. For asphalt macadam the cost is about $1.25 per square yard.

But the life of these latter pavements under conditions on this island is only 6 or 7 years, while that of reinforced concrete is more

than 12 years. Also the amount of money necessary to keep the pavements in repair is much greater for the macadams than for the reinforced concrete. These two facts together would indicate that reinforced concrete is actually cheaper in the long run.

The probable cost of a first-class reinforced concrete road of the type necessary to be built on this island would be about $25,000 to $30,000 per mile. The city and county of Honolulu are paying about $27,000 for similar roads.

TIME OF CONSTRUCTION.

Judging from the progress made on similar roads built on this island, one construction gang complete could finish about 300 feet of road per day.

Road Work on the Punitive Expedition into Mexico

BY

Capt. ERNEST GRAVES,
Corps of Engineers.

This article attempts to describe the road work actually done on the expedition into Mexico, and to give an idea of the problems encountered and the methods used to solve these problems. It is not at all certain that it is proper to use the term "road" in describing this work, as the route used in many places could hardly be called a road. In some instances this route has been very properly spoken of as a "trail across the prairie."

In discussing the subject at hand, the detailed points brought out must necessarily be those observed by one person. This person was with "H" Co. Engineers (later "B" Co. 2nd Regt. Engrs.). The work of this company was varied enough to make its work typical of all the work. What the other companies did can be spoken of only in general terms.

When the methods that were used to try to keep the road under discussion passable for truck traffic are considered, it should not be forgotten that at no time during the expedition was anyone able to make plans that would require more than one or two months for completion. . . .

The route that was used for the supply of the Punitive Expedition was probably the first natural road of such length that was ever subjected to truck traffic on a large scale. The supply of the military force was accomplished by means of truck trains and wagon trains and by means of shipments on the railroad from Juarez, Mexico, to Colonia Dublan, Mexico. Only two or three wagon trains were used, while ten or fifteen truck trains were constantly used. It is estimated that at least an average of one truck train (consisting of about 30 trucks) a day passed over each point in the road each way, making about 60 trucks over any one point per day. The trucks used were of many types, varying in capacity from one and one-half tons to four tons. However, after the first

stages of the expedition, one and one-half ton trucks were the ones used mostly. This means that the road was subjected to traffic which produced a wheel pressure of from three-quarters of a ton to probably about two tons. Of course, this traffic made the road work exceedingly difficult.

The route over which the supplies were carried varied a good deal. One road was used until worn out and then traffic was shifted to another. This shifting was both general and local. Practically the entire road to El Valle (180 miles), was changed and local changes were made where bad spots developed.

When the expedition first went into Mexico the route taken was as follows (see map):

Columbus, Gibsons Ranch, Boco Grande, Epia, Ascencion, Ojo Federico, Big Bend, Corralitos Ranch, Dublan, Chocolate Pass (Charcos), Galeana, El Valle, Cruces, Namiquipa. Namiquipa was the farthest point south to which an advance base was carried. Truck trains went about 60 miles south of Namiquipa to San Antonio and occasionally to other places. No work was done on roads south of Namiquipa, so only the roads as far south as Namiquipa will be considered in this article.

The road first used consisted of a natural trail, which generally followed a level plain in a river valley, but at several places passed through mountain passes from one plain to another. At some places the trail ran through the mountains for distances of from 30 to 35 miles. The trail from Columbus to Ojo Federico was mostly flat. It passed over hills for short distances north of Gibsons Ranch and at Boco Grande. From Ojo Federico to Big Bend was mostly hilly. From Big Bend to Chocolate Pass the road was through flat country. After two or three miles of hills at Chocolate Pass, the road passed from the valley of the Casas Grandes River to that of the Santa Maria River and followed the latter river to El Valle. From El Valle and Cruces to Namiquipa the road left the river and was very hilly, and rough through the hills.

The above described route was first used. Later, when it became evident that the Expedition would remain in Mexico during the rainy season, the route was changed to the following: Columbus, Palomas, Windmills, Ojo Federico, Corralitos Station, Dublan, Charcos, San Joaquin, El Valle. Before the rainy season all troops had moved north of El Valle and the road south was no longer in use.

Both of the routes passed through a country devoid of timber. There was absolutely nothing that could be used for bridges; *i. e.*,

MAP OF ROADS
USED BY
PUNITIVE EXPEDITION IN MEXICO.

nothing that would last any length of time. Most of the stream beds were dry the greater part of the time, and generally no crossings were necessary because the arroyos never had water in them for more than a few hours at a time. The exceptions to this were the Casas Grandes River, the Santa Maria River, and irrigation ditches in the towns. Even these rivers were fordable, except during parts of the rainy season.

The Engineer troops with the Punitive Expedition were three companies of the 2nd Battalion of Engineers under Maj. Lytle Brown, Corps of Engineers. On the road work these companies were assisted from time to time by infantry troops on the expedition, in varying numbers and at various places, when and where the amount of work necessitated more troops. At first only two Engineer companies (''E'' and ''H''), were on the expedition, ''G'' Co. being left at El Paso. Later (March 24th), ''G'' Co. came from El Paso and took charge of a section of road work. The portion of road assigned to each company varied from time to time as the locations of troops along the road varied. As the expedition moved south ''H'' Co. worked from one section to another until it reached Namiquipa, where it stopped and worked back to Dublan. ''E'' Co. marched south to Ascencion, then worked in that vicinity. When ''G'' Co. came it was stationed at Boca Grande and worked in that vicinity. Later ''G'' Co. moved to El Valle and worked from there to Dublan. ''H'' Co. worked from Namiquipa to El Valle, and ''E'' Co. worked north of Ascencion. At this time a battalion of the 24th Infantry was working from Dublan north to where the road left the river bottom. When the troops moved north to El Valle, ''H'' Co. moved to El Valle, ''G'' Co. to Ojo Federico and ''E'' Co. to Vado de Fusiles (20 miles south of Columbus). At this time the road was being changed and preparation was being made for the rainy season.

The engineer companies marched to their various stations in the first place, doing pioneer work on the march. When they stopped and had to work back, they had obtained trucks from the Quartermaster's Department, and usually sent out working detachments on trucks. The first company marched into Mexico March 16th, 1916, and it marched and worked on foot until April 7, 1916, when it received two trucks from the Q. M. Department. From April 7th to April 25th detachments of this company moved and worked back and forth between Dublan and Namiquipa (117 miles), using two trucks. On April 25th authority was given to employ hired labor.

After this time hired labor was used and more trucks were supplied, as they were urgently needed.

On August 1st, 1916, the 2nd Battalion of Engineers was organized into the 2nd Regiment of Engineers under command of Col. G. A. Zinn. This reorganization was carried out without a single day's break in the road work, and the difficulties of keeping work going, while transferring men and property from organization to organization, can hardly be described. One company, divided along a hundred miles of road, in working detachments, is difficult enough to manage, but if you transfer men out of such a company, while work is going on, you will find yourself in a most hopeless muddle of paper work and property.

The work done on the trail varied from the most hurried pioneer work on the march, to grading and surfacing the road for truck traffic in the rainy season. Of course, the length of road was so great and the time was so short that no real road could be built. Efforts were directed towards keeping the trail passable and the work was always so far behind the conditions that nothing more could be attempted.

On the march down, generally the trail was good enough. However, at places in the hills or at arroyo crossings, work was necessary. At Boco Grande, for instance, there were places where a wagon might turn over, or where there were large boulders that would be very hard on trucks. The high sides of the road were cut down, and deep washouts, with vertical sides, were filled with rock. Where the trail ran over arroyos the crossings were fixed by grading down the slopes, removing the rocks from the bed, and in some cases shoveling out sand which might stop a truck (no material was available for bridging). At Ascencion, a small bridge was constructed over an irrigation ditch by using lumber taken out of an abandoned house. At the same place wire fences were cut to permit traffic to go through fields and around mud, caused by overflow from irrigation ditches. In Galeana and in El Valle some small bridges were placed over irrigation ditches, either with cottonwood or scrap lumber found nearby. These soon broke all to pieces and trucks simply ran through the ditches. On the mountain road between El Valle and Namiquipa quite a good deal of work had to be done taking large rocks out of the road and fixing arroyo crossings, so that trucks could make the slopes. Sand had to be shoveled away in some cases. Large boulders were blown out with explosive.

After the road had been gone over hurriedly to remove the

worst obstructions, about April 7, 1916, each company received two trucks with which to move its men up and down the road to work on the worst places. These two trucks would carry about 30 men with their tools and rations. One company, for instance, had to work about 120 miles of road. Nothing could be attempted except to remove the worst obstructions. Thirty men of ''H'' Co. moved continuously back and forth from Namiquipa to Dublan (120 miles) for about a month trying to better the trail. The rocky places and the arroyo crossings could be improved, but long stretches of flat road got worse and worse, and no remedy could be applied. This condition was worse north of Dublan than south of Dublan. The flat road simply wore into a great mass of dust. The holes got deeper and deeper, and anything put into them was simply thrown out into dust by the first truck train. In the hill country there was plenty of rock, both in the road and out of it. After the rough rocks were taken out of the road, holes developed which rapidly used up the trucks. It was found that it was useless to fill holes and depressions with gravel or small rock. Trucks would simply crush out the dry stuff. No water was available. Where deep holes developed, it was necessary to dig them more or less square and to pave them with one or two man stones, placing some fine gravel on top. The mountain road could be helped this way, but the flat stretches had no rock nearby. The irrigation ditches in El Valle and Cruces gave so much trouble that finally trails were made around both places. The ditch crossings could be so graveled that trucks could cross but the sides of the ditches were being continually cut by the wheels, so that the water would flood the road, which in many places was lower than the irrigation ditches. Bridge material could not be found.

At Boca Grande, ''G'' Company made a pretty good road through the hills, but could do little to help matters on the long flats north and south of that place. A long stretch of sand north of Galeana was almost impassable and no remedy could be thought of. At such places a new route had to be found.

About April 28th, authority to hire labor was obtained and working gangs were organized at different points along the road. ''G'' Company was moved to El Valle and given the road from Dublan to El Valle, while ''H'' Company had the road south of El Valle. ''E'' Company and a battalion of the 24th Infantry worked north of Dublan. At first it was difficult to get labor, but soon the Mexicans learned that they would really be paid a dollar (American

money) per day and were glad to go to work. This was true at Dublan and south, but the northern part of the road had to be supplied with labor from labor agencies in El Paso.

While Mexicans would promise to work and would really go to work in considerable numbers, still sticking to the job continuously was another matter. They would generally quit after each pay day, and they might or might not resume work after their money was spent. In order to get them to work, weekly payments had to be made because they said they had to have money to buy food. These frequent paydays, of course, caused much delay in the work. South of Dublan, replacing or getting back labor after pay day was not so difficult, as it was farther north where labor came from El Paso. These laborers would quit and leave after receiving pay, and a new lot would have to be sent from Columbus on trucks.

The difficulties of getting work done quickly over long stretches of road, where necessarily many gangs had to be worked in separate localities, were greatly increased because existing orders required a guard of not less than ten men to accompany every gang and every truck. This regulation was not enforced when there was great demand for road work, but later when it was enforced it proved a great hindrance to accomplishing results.

With the instructions to hire labor came instructions to prepare road for the rainy season, which was said to begin about June. This proved to be a fallacy, as the rainy season did not start until about August 1st.

In order to be ready for wet weather, it was necessary to have a drained road. In the hilly country this was comparatively easy, but the greater part of the road was over flat river bottoms, which looked as if they would be covered with water during all the rainy season. Natives told stories of heavy rains which made one think the task impossible. However, the rainy season did not prove to be very wet. The annual rainfall is from 10 to 12 inches, so there cannot be a great deal of water. The two rivers that had to be crossed (Casas Grandes and Santa Maria), were supposed to be unfordable for periods as long as one month. Too much work was necessary to prepare the route in use before the rainy season for wet weather use, so a new route was picked out which contained less low flat country and which crossed the Casas Grandes River nearer to Columbus, where bridge material could be obtained. Parts of this route already contained roads and parts had no roads at all. Only a month was supposed to be available for work before rain, which

was expected about June 1st, but did not materialize until about August 1st.

When the new route was first decided upon it was not known just how much work could be completed before rain, so different expedients appeared advisable in different localities.

The wet weather route has been outlined above. From Columbus to Vado Fusiles (19 miles) there was already a trail, but as it passed over flat undrained country it appeared best to place the road on an old railroad grade which had been in existence for years. This grade had to be patched in places, and small bridges and culverts had to be put in.

At Vado Fusiles a timber trestle bridge had to be placed over the Casas Grandes River, the timber being hauled 19 miles from Columbus. The sketches show the design of this bridge.

It was feared that a trestle bridge might wash out, but the time required to get material to the spot necessitated the use of the minimum amount of lumber, so it was decided to take a chance on a trestle bridge. The bridge stood through the rainy season without mishap.

From Vado Fusiles south for about sixteen miles an existing trail passed over a flat country which was not drained, and which required grading. Then it went through some hilly country in which drainage was comparatively easy. From these hills the existing trail passed down into the flat country containing Ascencion, Ojo Federico, and some lakes. This trail was used for a while, but later a road was located on new ground along sloping hillsides. It went around the flat country, and came to the existing trail near Ojo Federico. This new road had to be cleared of mesquite. In it there were long stretches of fine sand which were almost impassable for trucks in dry weather.

From Ojo Federico the road followed the existing trail to Capuchin Pass, from which point it left the old road and followed the sloping hillsides, to the eastward, to Corralitos Station. A portion of this stretch had to be cleared of mesquite. From Corralitos Station a new road was made to Dublan, alongside of the railroad.

At first it was not expected that grading would be done all along this route. In fact, south of Ojo Federico no new route was laid out. The existing trail for about 24 miles north of Dublan followed the Casas Grandes River, and was flat and undrained. Since it did not seem possible that grading could be accomplished here and since the road would most certainly be muddy, something had to be

Bridge at Vado de Fusiles

Elevations of Typical Bents

6 double bents of type shown, 4 single bents at each end; total, 14.

All posts and sills of 4″ × 8″ placed double.

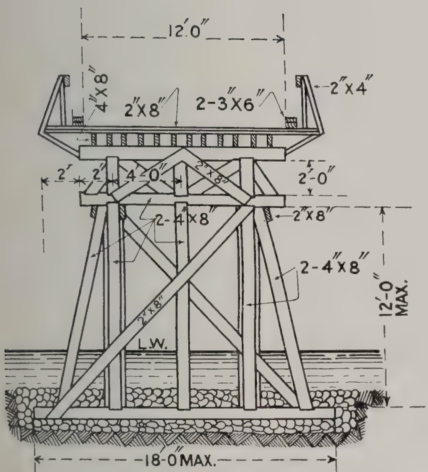
Cross and sway bracing, 2″ × 8″.

Stringers, 4″ × 8″.

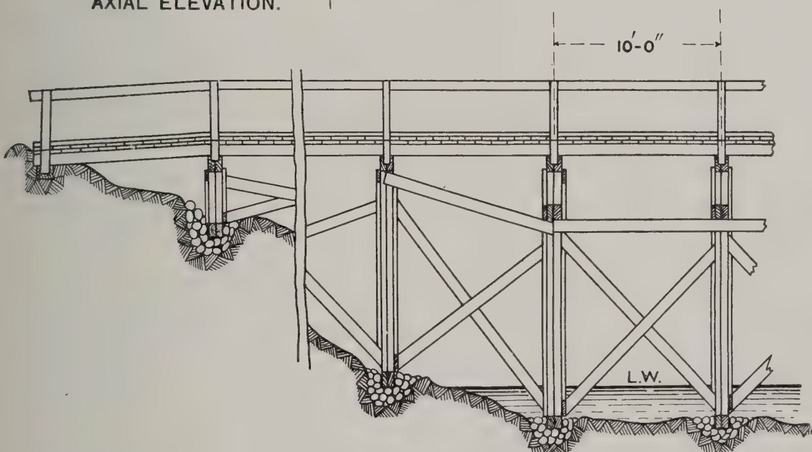
Flooring, 2″ × 8″, laid double, broken joint.

Side rails, 3″ × 6″, placed double.

Bents, 10′ 0″ o. c.



AXIAL ELEVATION.



SIDE ELEVATION.

done. So a battalion of the 24th Infantry with hired native teams went to work to put gravel on the existing trails, which had already worn into two deep ruts. Gravel was hauled from the river bed, which was almost dry. Before it was possible to start the new grade in this section the 24th Infantry had put 4 inches of gravel on this entire section. The gravel did not pack readily, and was used by trucks only when they were forced to it. . . . It came into use again after the rainy season.

Finally, all of the above described route and in addition 10 miles south of Dublan (total 130 miles) had to be graded. Even the railroad grade from Columbus to Vado had to be graded in places. In grading no attempt was made to follow the existing trail, even when it was close by. A new line was laid out which was made as nearly straight as possible, and the least possible number of changes in direction were made. The machines used could work to much better advantage in straight lines, and maintenance of straight lines was easier. The road in places would be straight for a length as great as 15 miles.

At first several different kinds of graders and tractors were used. In places scrapers were used. Steam rollers were tried on the grade before wet weather and after wet weather. All of the tractors tried proved too frail and of little use, except the caterpillar tractor. Small (6-foot blade) graders could be used with tractors, with trucks, or with teams. The large (12-foot blade) graders pulled by a caterpillar tractor proved to be the thing to use.

The work of grading, when finally unsuitable machines were discarded, was done simultaneously in the three sections by the three companies, "E" Co. had 2 tractors in the vicinity of Vado, "G" Co. had moved to Ojo Federico and had 3 tractors in that vicinity, and "H" Co. had moved to Dublan and had 1 tractor in that vicinity. On one occasion when "H" Company's tractor broke down, 2 tractors were hired for a short time, 1 a Hart Parr machine found at Corralitos Ranch, and the other a steam tractor hired in Dublan. While these machines made some appearance of work going on, while the Holt tractor was idle, they accomplished very little.

The grading work was done both in the vicinity of water and far from it. Since the machines used gasoline and required only a few men to operate, the water supply question was not exceedingly difficult. Long stretches (25 miles for instance), were graded, water for the men being carried by trucks. Three graders could start out

with crews and 4 Jeffery trucks could follow along and bring enough camp equipage, gasoline, water, etc., for the crews. Water could be carried in a tank wagon towed by a Jeffery truck. When supplies gave out, trucks could be sent for them.

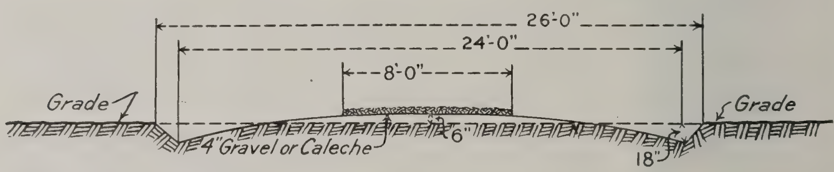
In grading a long stretch it was very essential to economy in work and time, that there should be a minimum movement of tractors when not actually grading. It was unnecessary to lose time moving back and forth from camp, if the place where tractors would be at night was carefully computed in advance, so the camp could be located there. Usually the grading did not stop until dark, so camp and food must be provided for the crew when it arrived. Of course, the machines had to be in camp at night where the guard could keep them from being tampered with. On one occasion a tractor was left out over night and the next morning it had been disabled by some meddler.

A gasoline caterpillar pulling a large (12-foot blade) grader could grade as much as two or two and one-half miles of road per day, provided there were no mishaps. Apparently the most important thing that a novice could look out for to prevent a breakdown was lubrication. If the machines were kept properly oiled, they were likely to keep running. They were operated by both civilians and by soldiers, whichever were available. One had to try anybody who said he could do it. Of course, one machine rarely graded two miles a day. Mud, sand, breakdowns, etc., frequently prevented any progress at all in one day. On one occasion Lieutenant Somervell graded from Capuchin Pass to Corralitos Station (about 22 miles) in five days with two graders, each being pulled by a tractor. The rate of progress is greatly enhanced by working in straight lines, as the graders and tractors are not easily steered on crooked lines. The stretch above referred to had only one change in direction in it. Of course, the best progress is made if the first line to be cut is carefully marked ahead of the machines, so that the crew has nothing to do but follow a clearly marked line. The line can be easily marked by sticks about 4 feet long with a white rag attached at their tops. These sticks can be small enough to stick in the ground by hand. There should be a marker about every 200 feet.

Another way to make progress is to turn around as few times as possible. Turning the tractor and grader is slow, so as long a stretch as practicable should be broken on the first cut. By careful thought, the stretches to be graded can be so arranged that the

machines turn around the minimum number of times, and still stop actual work adjacent to camp.

The 12-ton Holt tractors, which proved the most successful of any tractors used on the road work, have a bearing pressure on the ground of about 7 pounds per square inch. These machines will pull a load through mud or sand in almost any condition. However, even these tractors encountered places where they would not work. On one occasion, a tractor pulling a grader just south of Dublan simply sank down in the mud and could not get out. A little ingenuity often could save much time. On the occasion referred to, after an entire half day had been spent in moving about 400 yards, it was found that the muddy places could be gotten over as follows: Fasten the grader close up to the tractor and grade, watching the tractor caterpillar wheels closely. Just the second that these wheels begin to slide on the soft ground, stop before sinking begins and



Cross-section of Road.

Scale, $\frac{3}{16}'' = 1'\ 0''$.

unchain the grader. Without the load the tractor will go over the soft spot. Then fasten the chain extended and proceed with the grading until grader is across the soft spot, when grader can be chained on again, close up. The time lost changing chain connections will be nil compared to that lost by getting tractor down in mud. Frequently, grading can be done with a long chain which allows grader to be steered where desired without tractor having to go directly in front over soft ground.

The cross-section of the grade is seen above.

Care should be taken not to make the crown too high, so that there is too much freshly cut earth to pack. The lower the crown, provided it drains, the quicker will it bear traffic. It is necessary that a dirt road be this width for trucks to stay on it and not to ruin it the first time they go on it. On any narrower grade the trucks will be continually sliding off, and, in addition they will push the graded material into the ditches.

This grade can be put up by 7 or 9 cuts with a 12-foot grader.

This is done by two cuts to make each ditch, one cut on each side throwing material to the center, and one trip down the center scraping the top smooth, total seven trips. If the width is not carefully made or if the work is not carefully done, two more trips (one on each side), are necessary to throw earth to the center. This method works in soil comparatively soft and firm. Harder materials, as well as muddy materials, require more work.

The machine runs from 2 to 2½ miles an hour pulling a load, and from 3 to 3½ miles an hour unloaded. Time is lost oiling and cleaning. On the work in question, the machines were supposed to work 10 hours a day. However, oiling and cleaning in the mornings and in the evenings consumed at least 2 hours of this time, and additional oilings were made between starting and noon, at noon, and at stopping time.

The graded road to Dublan was finished about August 5th, just before any heavy rains occurred. Later, after the road became impassable farther south the road was graded about 10 miles south of Dublan.

South of this grade the road ran on hilly ground to El Valle (about 50 miles), and no attempt to grade was made. This road had been selected with a view to travel in rainy weather and was well drained. Long stretches of it were originally on unbroken ground which was soft at first but developed into a pretty fair road when traveled over after moistened by rain. Of course, there were many arroyo crossings which had to be sloped and paved because of lack of bridge material. Places had to be crossed which required a continuous paving of two-man stone.

At San Joaquin, the San Joaquin River (dry most of the year) had to be crossed by sloping the banks and paving the bottom. Once or twice after heavy rains this crossing developed into an impassable ford.

On the whole, the road south of the grade to El Valle was very good during the rainy season. In dry weather it got dusty and rough.

At El Valle the Santa Maria River was crossed by a trestle bridge about 150 feet long and a rock causeway about 1,000 feet long. This river was supposed to be unfordable for as much as a month at one time during some periods of the rainy season. Of course, it appeared to be the height of folly to so close the natural opening of the river by a causeway of rock, and to expect a trestle bridge to stand in such a closed way. About five-sixths of the nat-

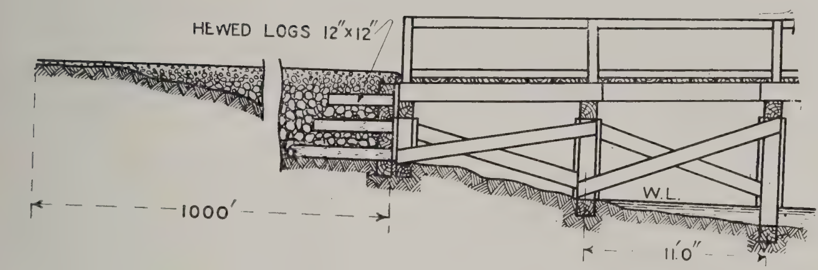
ural opening was closed. However, like everything else done on the road, it was a case of necessity and of doing the only thing possible. One simply could not get bridge material to the site, sufficient to construct a longer trestle. This may be unexplainable to those sitting by their firesides or at their desks at home, but it was a fact just the same. On one occasion it was impossible to get 500 picks south of Dublan. Only food could be hauled. The lumber for the bridge at El Valle was shipped by rail to Dublan, and hauled by native wagons 60 miles to El Valle. It took about 50 wagons about 4 days to get the lumber to El Valle. The causeway was constructed in about 2½ weeks by 500 natives and 150 native wagons, and the trestle was erected in about two days. On opposite page is shown a sketch of the trestle erected.

The sills were buried 1 or 2 feet in the rocky bottom, and one and two man stone were piled around and on top of the sills. Of course, no one thought that this bridge would stand if the river should rise much, but it was hoped that no great rise would occur.

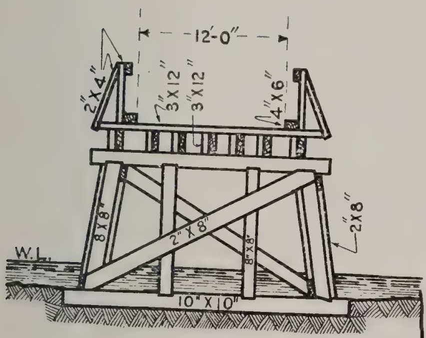
After the rainy season started (about August 1st), the Santa Maria rose 2 or 3 feet and became a stream about 125 feet wide with swift current. While the stream was at this stage it could be forded by wagons. Trucks did not try this ford, but if they had they would undoubtedly have had trouble. Of course, under these conditions the bridge was quite a convenience.

About August 28th the river rose suddenly almost to the bridge stringers, and a mass of small drift collected against the bridge, which broke about the middle. Both sections of the bridge swung downstream against the banks, lodged there, and became partially covered with sand. Orders were issued immediately to have the bridge rebuilt. So a detachment of about 10 men went from Dublan with tools, and with some small sized lumber which happened to be at Dublan. Before this detachment reached the bridge site, the river had fallen to a stage fordable by wagons. When the condition of the bridge was seen, it could not be told, at first, just how much of the lumber in it had been lost, so a wire was sent ordering from El Paso enough lumber to rebuild half of the bridge.

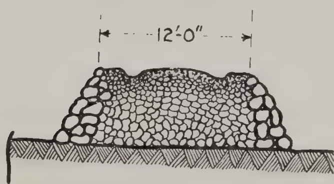
The troops on the other side of the river had about 5 days rations. Of course, wagons could ford the river below, but it was desirable to make it possible for truck trains to cross. The lumber ordered from El Paso could not possibly get there in less than about 5 days, and probably would not be available for a month. If the



Side Elevation.



Cross-section through Bridge.



Cross-section through Causeway.

Scale, $\frac{1}{8}'' = 1'\,0''$

BRIDGE AT EL VALLE, MEXICO

bridge was to be replaced rapidly, it was necessary to put it back just as it was before. If it was not replaced just as it was, there would certainly be a shortage of lumber, and no suitable material was available to replace anything but the flooring, a small portion of which might be replaced by 1 by 12's tripled or 2 by 12's doubled. A small quantity of these sizes had been brought from Dublan. To avoid any possibility of running short, and also to attempt to locate the trestles exactly where they were at first, a wire was sent to the officer who first constructed the bridge, asking the distance across and the exact spacing of trestles center to center. This information was gotten promptly.

Then the detachment was increased by some soldiers on road work at San Joaquin, and some natives on the same work. This detachment went to work to pull out the bridge material and reconstruct the trestle. It was difficult to get this material out, because it was bound together with twisted bolts and was half buried in sand. However, by fastening ropes to a trestle, a number of men could finally pull it loose and drag it out. The river was then about 3 feet deep and running like a mill race. Trestles, stuck in sand and pulled on, were worked loose, probably by reason of current moving sand. As the different parts of the bridge were taken out they were marked so that they could be put back just as they stood originally. Care was taken to break and lose as little as possible. One complete bay of the bridge was found about 2 miles downstream. At the end of the first day all material had been salvaged, the nails had been removed and lumber stacked. Some of the trestles were intact, some had been pulled to pieces. Some of the cross-bracing had been lost or destroyed, but only one other plank was missed. On the first day, one bay was replaced adjacent to the abutment.

The second day the bridge was replaced with the exception of one bay, which was placed on the third day. The first difficulty encountered was getting the trestles down in the bottom as low as they were at first. This was done by placing them, and having men work the sand and rocks out from under the sill with their feet until the trestle was at proper level. The water was so cold and the current was so swift that it was hard to keep either soldiers or natives in it for any length of time. Reliefs were used to allow men to get warm. If the bottom was prepared before the trestle was placed, the current would fill it with sand before the trestle could be placed. In order to get the trestles out in the stream, it was necessary to put

them in upstream and let them float down, holding them with a rope. Fifty men could not pull a trestle upstream if it was put in below the bridge. After a trestle was gotten in approximately the right place, it was raised to a vertical position by hand. After the work got near to midstream, the current was so troublesome that a shear was erected on the bridge, and the trestles were lowered into place from above. This method was much slower than the hand method. The middle trestle was placed by hand, *i. e.*, hand and ropes. This was possible because men could pull on it from both sides of the stream.

All the trestles but one were gotten down to proper level, pretty well. The floor had to be sloped over this one. Apparently the large rocks originally over the sills had been carried away by the current. The structure was replaced by working from both sides towards the middle. When the middle trestle was put in, the 2 spans adjacent to it were about 12 inches too long. The stringers which were supposed to lap were not quite long enough to span this, middle of cap to middle of cap. However, a 4 by 4 was drift-bolted to each side of the middle cap, and this gave the stringers enough bearing. They were also spliced together over the cap with 2 by 12's.

After the bridge was completed, on the third morning the floor was leveled in place by shimming under the stringers. Then large rock were hauled from 2 miles away and piled around the trestles, up to a foot over the cap. These rocks varied from one-man stone to stones which required 3 and 4 men to handle them. They were dumped off the side of the bridge and rolled into place. This work in the cold water was very hard on the men, and it was difficult to get the stone properly placed. It was feared that these piles of stone, by closing the opening, might do more harm than good.

It seemed fairly certain that if the river rose again the bridge would go again, but it was hoped that the river might not rise again. However it did, and the bridge went as expected. Early in September the same thing happened, and the bridge was replaced about the same way. By this time the lumber ordered the first time was in Dublan, so materials were on hand to replace any losses. The first time the bridge was replaced the longitudinal bracing was omitted in every other bay in order to give the water freer passage. Such longitudinal bracing as was placed, was placed above existing water, but the second time the bridge was replaced all

longitudinal bracing was omitted. Originally all bracing was bolted. When replaced it was all nailed.

This bridge, although it went out twice, was probably cheaper and more expedient than a better structure. Both times it went out it was replaced rapidly, and nothing serious occurred on account of its going out. Placing it 3 times was probably cheaper than a good bridge would have been. However, price was not the governing consideration. Materials could not be got to the site within the time available to build a first-class bridge, so nothing else could be done.

South of El Valle the road ran through hills and mountains all the way to Namiquipa, about 60 miles. There were many arroyo crossings, both large and small. It appeared fairly certain that these arroyos could not remain impassable for more than a few hours at a time, so no bridges were absolutely necessary. Whatever the necessity no material for bridges could be obtained. The road in this section could be fixed for rainy weather, because there was rock and gravel close by any locality that needed it. The steep rocky hills would, of course, be better with occasional rains than in dry weather. So when orders were received to prepare the road for the rainy season, gangs of native wagons were put to work placing stone and gravel on the stretches where water would produce mud.

In places where water was nearby the proposition was fairly simple, although the load that a native wagon would carry was ridiculously small. The mules, which pulled the wagons in teams varying from 4 to 6, were small, lean, poorly fed, and in many cases crippled. The wagons were generally almost in a state of collapse. If the team and wagon could carry a load varying from ½ to ⅔ of a yard on level ground, frequently the pull out of a stream bed where gravel was obtained would make the loads actually hauled even less. The cost of such work at $5.00 per team per day was too large to allow anyone to keep track of it.

However, the proposition in all the stretches of this southern section was not so simple. There were lengths 8 to 10 miles long in which no water could be found for men or animals. The only possible solution was to camp the men and haul water to them. Trucks could not be gotten in sufficient numbers to haul gravel, but a few trucks were available for hauling water. The teams simply had to make the trip from water to work and back each day. Just as this scheme was about to be put into effect it came near

being completely blocked, because 36 water-cans could not be gotten. . . . In the early part of June all troops were moved north of El Valle, so this work stopped after it had been gotten sufficiently in hand for it to be evident that the necessary result could be accomplished.

Many episodes, such as the water-can affair, could be related to show the difficulties of the situation. However, it is not necessary to demonstrate a fact, which anyone knows must exist under conditions of campaign, even though the campaign be bloodless. An experience with trucks and truck drivers might, however, be interesting, viz: Four Jeffery trucks were sent from Columbus to report to the officer in charge of road work south of El Valle. This officer was notified by wire of this fact. After about a week's waiting, he began wiring to discover the location of these trucks, but could learn nothing. He could not even get answers to his wires. Finally, one truck showed up with a young civilian driver, who said the other trucks had gone back to Columbus. This driver insisted he was to return to Columbus by the next truck train, and a guard had to be placed over him to keep him. After one day's work his truck stopped running and he did not know what was the matter with it. So an engineer soldier fixed the truck and ran it while the civilian acted as kitchen police for the detachment (under guard, of course). The situation might have been most amusing if not so serious.

After the road had been graded all the way to south of Dublan, and before there had been any rain to speak of, it had been run over in places by the trucks, but generally they had not gone on it. Where trucks had been on it, it was simply a pile of fine dust. A truck could hardly get out, if it got into this soft material. Most of the road was a pile of loose dirt, and no truck had gone on it. Practically everyone thought the grade would never be used. It appeared that truck trains would never run on it enough to pack it, and it was feared that unpacked it would be very muddy when wet. Finally, the Commanding General ordered an F. W. D. (four-wheel-drive) train to travel the grade from Dublan to Columbus. This train packed a rut in the soft grade, and a rear-wheel-drive train soon followed in this rut, having been driven off the old trail by mud. After this, rain drove all traffic from the old trail to the grade.

Water soon changed the pile of dust into an elevated strip, which after rains was the first place to be passable. Of course, a dirt grade when wet is cut by traffic, and unless it is quickly

worked on will soon be ruined. It became necessary to organize the road gangs into maintenance gangs and surfacing gangs.

The character of the material of the road, of course, varied in different localities and required different treatment. Certain places could be maintained without any metal surface. Others required some kind of a surface. Certain sandy stretches were fairly good when wet, but a few dry days made them almost impassable. When the sand was wet and best, the same rain might have turned the road a few miles away into an impassable mud hole.

Wherever surfacing materials were nearby surfacing was done. In some places gravel was used. In others ''Caleche'' was the only available surfacing material. It, when wet, makes a very good surface. This surface, however, does not last very well under heavy traffic, so it has to be frequently patched. There was not time to get rock crushers, where rock was available, even if everyone had not believed that the expedition would be withdrawn before a crusher could be installed. There was no hope of surfacing the entire road in time to do any good, so the worst places only were worked on.

The surfacing presented a different problem in each locality. If the haul was not too long, and there was water nearby, teams could be used. If the haul was long, trucks or wagons pulled by tractors had to be used. If there was no water close by, it was impossible to camp teams near enough to the work to do any good. Trucks could not be obtained in sufficient quantities, and due to uncertainty of length of stay of the expedition, dump wagons for the tractors to pull were not ordered in sufficient numbers.

The matter of getting something to work with, especially trucks, was simply a matter of the apparent necessity. If the truck trains traveled without much delay, then nothing could be gotten for road work. When two or three trains had got stuck up to the bodies of the trucks in the mud, and things looked as if people might go hungry, then means to work would be provided. Of course, each time this happened the remedy was too late for that particular condition, but it might prevent its recurrence. After some bitter experiences of this kind, the provisions for road work were fairly generous.

Surfacing with teams was limited to the 15 miles north of Dublan. As previously stated, the amount of material carried by a native team was ridiculously small. A sandy stretch about 7 miles

long was partially surfaced with Caleche. The first 1 or 2 miles was done fairly quickly, but when the haul got longer the work went very slow. Later trucks were used on the long haul, but not enough trucks could be put on the work to get rapid results. Then a tractor pulling about a dozen dump wagons was used. Before the stretch was completed, the rainy season was over and the work was stopped, and traffic went back to the original trail. No attempt was made to surface any more than a strip 8 feet wide in the middle.

On the northern part of the road, tractors pulling dump wagons were used almost exclusively, and the worst places were thus surfaced. Work in this section was hard to accomplish, except in certain localities where there was water. In the long stretches when there were no streams and no wells, wells had to be drilled or water had to be hauled to labor camps. Several wells from 500 to 800 feet deep were drilled.

When the grade was first finished it was planned to establish a maintenance camp every 10 miles. This was not accomplished entirely because wells were not drilled quickly enough. However, for about 25 miles north of Dublan it was feasible and was done. The idea was to put 2 teams with drags at each one of these camps, and to have each team drag 5 miles from camp and back each day or after each truck train had passed. This scheme worked pretty well when it was put into effect.

Where the road surface consisted of adobe it dried out remarkably quickly after a rain, and was left compacted into a very good dirt road. If a truck train did not go on it too quickly after rain, it was not damaged much. The first 8 miles north of Dublan was mostly good during the rainy season by reason of the material and constant dragging. It was a good example of what dragging may accomplish. A truck train was seen to go on this grade within 2 hours after a hard rain, and do but slight damage to it. However, such a road must be dragged promptly after it has been rutted, and exactly at the time when the material is of the right constituency to be dragged smooth. After this it will bake hard and smooth with most astonishing rapidity. The dragging *must be* done with the *utmost dispatch* and with intelligence.

The drag used on the Dublan section was improvised from logs or 3 by 12's and old wagon tires or scrap iron. A blacksmith shop was found at Corralitos Ranch, which luckily had around it tools

and scrap stuff with which drags could be fashioned. The sketch opposite shows this drag in detail.

A longer drag was tried first but it did not work well. The small, native teams had trouble pulling even this short one. Sometimes 4 native mules, sometimes 6 mules, and sometimes 8 mules were hitched to this drag. The trucks generally made 2 ruts in the road. The drag would go down filling in one rut and come back filling in the other. Where it appeared advisable to move any material, a small (6-foot) grader could be used. It was pulled by 1 or 2 army teams of 4 mules each, or by 2 Jeffery trucks.

By maintenance, such as is described above, viz: Graveling in places, dragging and regrading, the road was kept in fair condition during the greater part of the rainy season. On one or two occasions, things looked pretty bad. After a hard rain truck trains would be delayed for as much as two or three days, and it would look as if there might be a serious interruption of the supply of the expedition. However, these situations were not very numerous and the rainy season passed without any mishap. The wet season proved to be quite short and not very wet generally. There was no general rainfall, and heavy rains in limited localities gave all the trouble that was experienced. By the middle of September the season was practically over, and the problem developed into a dry weather problem again.

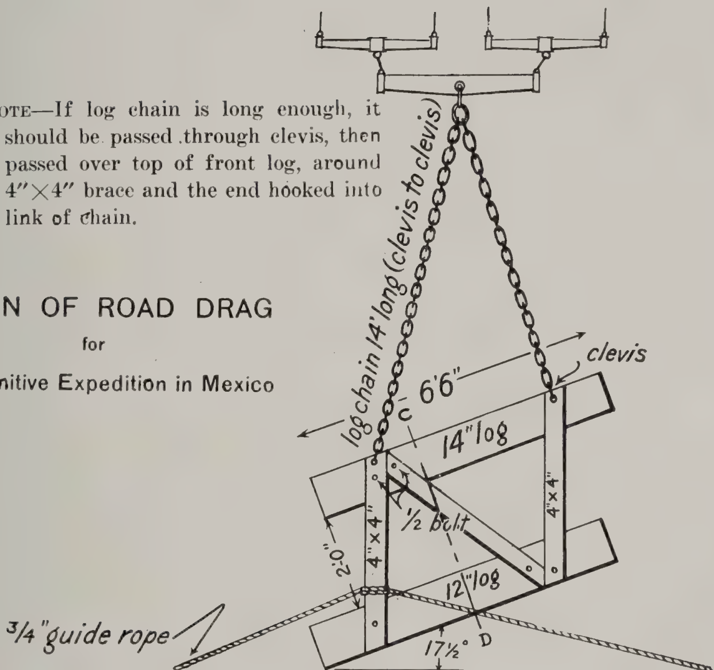
When roads began to get dusty again, the graded road soon began to wear out and to give trouble. Soon traffic went back to the original trail. It had been hardened and made smooth by rain, but it also began to cut up and to develop into chuck holes and dust. About this time Colonel Walker, who had relieved Major Brown in charge of road work, started a scheme of scraping off the top surface of the road (not the grade), and leaving the road a sunken road. This was possible now with the graders and tractors on hand, although it had not been possible in the previous dry season, when the machinery had not been gotten. When the scheme was first started, the idea was to scrape off the soft top surface and leave a firmer, smooth surface for the trucks. It was expected that this surface would soon cut up, and that it would be necessary to keep moving the road, scraping a new place each time the trucks cut up a scraped place. However, it soon developed that the sunken road could be kept in fair condition by scraping, and that it was unnecessary to make new roads. The lower material appeared to stand the traffic quite well, if it was scraped once or twice a week,

NOTE—If log chain is long enough, it should be passed through clevis, then passed over top of front log, around 4″×4″ brace and the end hooked into link of chain.

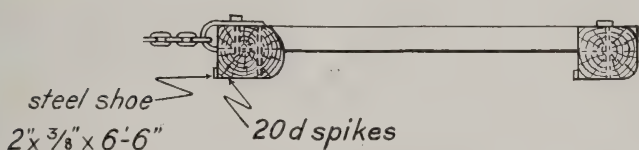
DESIGN OF ROAD DRAG

for

U. S. Punitive Expedition in Mexico



PLAN.



CROSS SECTION C-D.

and this scraping prevented the development of chuck holes, or excessive dust. The reason for the success of this scheme was never completely explained.

Railroads, both standard and narrow gauge, have been suggested. Neither kind could have been constructed in the time available. Either would have cost much more than what was done. Some of the mountain passes would have prevented a railroad on allowable grades, unless tremendous cuts requiring much time were to be made. A narrow-gauge road would not carry the tonnage. The procuring of equipment and materials for either kind of railroad would have taken much time not available. Neither kind of railroad would have prevented the purchasing of trucks, which had to be gotten to supply food at once.

A plank road was considered and might have been laid in time to do some good if transportation had been available to haul the plank. Such a road as shown in the "Engineer Field Manual" would have worked splendidly. However, this road requires 264 loads of lumber per mile of road, for the floor alone, counting a truck load as twenty 3 by 12 planks. (This was found to be what a truck could carry when bridge lumber was hauled.) Truck trains that ran during the expedition made about 50 miles a day. Supposing that 264 trucks could have been put to this use, which supposition is absurd on the face of it, after the first 25 or 30 miles of plank road had been laid, a mile per day might have been laid, and the other 90 miles might have been laid in 3 months. This might have been done, if the lumber could have been gotten in time. These approximate figures show to anyone who knew the conditions that this scheme was impracticable, so it is useless to discuss it.

The idea of laying a plank track consisting of two 3 by 12's for each wheel, with cross plank about 3 feet apart was considered. In fact, some lumber was gotten for this purpose but was never used. Personally, I do not believe that the trucks could have stayed on the track, or that the track would have stood the traffic. However, no transportation was available to haul this plank, which would have amounted to about 2/3 of that required for a plank road. Some track of this kind made of 2 by 12's was tried and failed completely.

Someone suggested corduroying the bad places. The idea is unexplainable because there was nothing with which to corduroy.

A macadamized road was even suggested, but how it was to be

constructed without rock or water was not made clear. Where it was most needed, both of these requisites were lacking.

A concrete track for each wheel was suggested, but there was no water. The cement alone would amount to much more tonnage than a plank road.

A scheme was considered and experimented upon, of using tractors with trailers to supply the expedition. This was based on the idea that the trucks were the most expensive part of the supply, and that tractors would not require a road any better than the existing natural road. Undoubtedly this method of supply would have been much cheaper than the one used. However, the supplies would have moved much more slowly than they did, and the operation would have required much more thought and care than the operation of truck supply. Organization of supply must have been much superior to what it was. This scheme might have been adopted toward the last if the expedition was to remain. However, the trucks were on hand, and everyone thought the expedition would soon be withdrawn. At first supply had to be rapid. No one knew what a tractor could do, anyway. In fact, it was some time after tractors were bought before it was found out just which ones were suitable. Several got at first had to be discarded entirely. Tractors, like mules and wagons, might have been cheaper, but results were much surer and simpler with trucks.

The work on the Punitive Expedition was very difficult. It was done under military emergency, and with the haste, accidents, and waste that must accompany such work. It should not be compared with a job which is slowly organized and slowly executed. When quick action and quick results are required, one must meet the conditions that exist, and get the best possible solution. While the best possible solution may or may not have been reached in this case, the results obtained were not bad.

Battlefield Illumination.

AN EXAMPLE OF PRACTICE IN BATTLEFIELD ILLUMINATION IN AMERICA

BY

Capt. R. C. KULDELL,
Corps of Engineers.

Battlefield illumination has now become a responsibility of all line officers, as well as of certain Staff Department Officers. All officers of the division commanding organizations will therefore give this subject study and will cause their organization to be trained therein.

This subject may logically be divided into the subheads:

(*A*) Battlefield Illumination with Searchlights (a function of Engineers).
(*B*) Battlefield Illumination with Trench Lights (a function of all branches of the Service).
(*C*) Battlefield Illumination with Rockets, Star Shells, Illuminating Grenades, Flares, etc. (a function of all branches of the Service).

(A) BATTLEFIELD ILLUMINATION WITH SEARCHLIGHTS.

Tactical use:

(*a*) To discover and keep in touch with the movements of the enemy during the night.
(*b*) To seek out and illuminate hostile objective, so as to fire upon them.
(*c*) To blind the enemy.
(*d*) To illuminate roads and possible hostile positions in the more distant foreground by periodically working the light.
(*e*) To search the near foreground.
(*f*) To support fire effect by steady illumination of hostile targets.
(*g*) To secure obstacles against hostile attempts at illumination.
(*h*) To disturb hostile works by alternate blinding and turning on the beam or by working the beam back and forth.
(*i*) To blind opposing searchlights.
(*j*) To support attacks in the foreground by throwing the beam in front of the advancing troops and screening their movements.

(*k*) To blind the enemy and disturb his forward march and firing capacity and confusing him by making him think his plans are discovered.
(*l*) To facilitate the landing of aviators at night.
(*m*) For anti-aircraft work.
(*n*) To give agreed upon signal, such as assembly points, or to indicate a threatened flank.
(*o*) To contribute to the rest of the men by diminishing the chance of surprise.

It is more difficult judiciously to employ searchlights in an attack than in defense, for while the defender will endeavor to explore and minutely search all the terrain in front of him, the assailant will seek obscurity to execute his movements and obtain surprise effects.

Searchlights on the Defensive.

In order to obtain sufficient illumination in each zone of terrain to be illuminated, it is calculated that there should be one light for each 1,000 yards of front.

The lights should be arranged in groups of three lights, one 36-inch light and two 24-inch lights, arranged thus:

1 DIVISION

o 24″	1000 yds.	O 36″	1000 yds.	o 24″	1000 yds.	O 36″	1000 yds.	o 24″
						o 24″ (Reserve)		
		1st Group				2nd Group		

This arrangement permits the use of the 36-inch lights for searching and the 24-inch lights for illuminating the target after it has been located by the 36-inch light. The 36-inch lights continue searching after turning over the target to the 24-inch lights. Searchlights work intermittently, the beam being exposed not more than 20 seconds at a time, this is to prevent ranging of artillery or rifle fire. The 6 lights for a division are attached to the Divisional Engineer train and commanded by the Commander of the train. When in operation, as shown above, the train commander commands one group and his senior lieutenant the other. In prepared positions the searchlights are accurately and scientifically located by the Division Commander, aided by his Chief Engineer.

The Division Commander keeps the searchlight commander informed of the situation, objective, his own intentions and those of regimental commanders in the vicinity. This information must be

given in good time in order to allow group commanders to define exact duties to the observers and operators.

For any sector of the defense there must be telephone communication between the Group Commander and his observers and operators and between the Group Commander and the Commander of the Sector of Defense.

When used for artillery fire the battery commander selects the most favorable position for observing the fire of his battery and for commanding the battery. The most favorable position for observing is about 50 yards to one side of the searchlight and slightly in rear of it. As soon as the target is discovered the battery commander has the fire prepared for the target. The light remains masked as much as possible. It unmasks immediately after the salvo is fired for the time necessary for observing the fire.

In connection with rifle and machine gun fire the searchlight is particularly useful. There must be complete communication between the infantry commander and the commander of the searchlight groups.

Searchlights on the Offensive.

In this case searchlights have fewer opportunities, as the attacker endeavors rather to take advantage of the darkness to surprise the defender's position which he has reconnoitered or attacked unsuccessfully during the daytime

Nevertheless, searchlights can be used in case of a check in the attack, due to heavy losses or other cause. The attacker's searchlights are then used as follows:

(1) They allow the attacker's artillery to fire against the defender's positions.
(2) They light up the defense and disturb the defender's proceedings.
(3) They counteract the defender's searchlights by blinding his electricians with their own rays.
(4) They neutralize the defender's searchlight beams.
(5) They establish a zone of light in front of the attacker's columns, lighting up the line of advance to his own troops and hiding it from the defense; this screen should be mobile and directed so as to deceive the enemy as to the direction of the advance.
(6) They help by revealing obstacles to their own artillery which is thus enabled to destroy them.
(7) They light up the whole defensive position when about to assault.

(8) Just before the assault they discover the enemy reserves just behind his firing lines.
(9) They cover the retreat of an unsuccessful attack.

Training in the Use of Searchlights.

The care and operation of searchlights is a highly technical duty and requires the long continued, systematic training of specially selected officers and men. For the care and operation of the carrying trucks, the gasoline engines, the electric generators and the lights themselves, electrical and mechanical engineers are required who thoroughly understand the theory and practice of the operation and repair of their units. For group commanders and observers, officers are required with experience gained only by constant practice in the selection of sites, and the operation of the lights over varied ground and under different atmospheric conditions.

The first step in training, therefore, consists in organizing a Divisional Engineer train for each Infantry Division and each Cavalry Division of specially selected Engineer Officers and men and assigning to each train two 36-inch searchlight sets and four 24-inch searchlight sets. The course of training for the train should be arranged by the train commander and be conducted continuously and systematically without the interference of other duties.

The second step in searchlight training consists in the use of lights with the infantry and artillery, separately at first, and in combination later. Such training requires the use of extensive maneuver grounds where actual firing can take place.

(B) BATTLEFIELD ILLUMINATION WITH TRENCH LIGHTS.

The Engineer Department has recently purchased a number of incandescent trench lights to be used on poles, and some storage batteries.

	Pounds.
Weight of light	24
Weight of pole	6
Weight of battery	85½

In addition a number of gas-electric generating outfits, to charge the storage batteries, have been purchased.

The trench lights, batteries and generating outfit will be maintained with the Engineer train. The batteries will be cared for, charged, and batteries and lights distributed to the infantry by the Engineer train. A battery will supply one light with current for five hours continuous burning. In trench work the lights will be

used only intermittently, so that one battery can probably be used two nights before recharging.

The distribution of trench lights is at present 24 lights for each division. One light will give sufficient illumination to permit rifle fire 200 yards in front of it. The beam is not a cylinder, as is the case with the searchlight, but a cone with an angle of dispersion of 30 degrees.

In action the lights are turned over to the infantry during the afternoon or evening with batteries charged. They will be located if possible in front of the fire trench. The operator is well protected, being entirely below the parapet. The light is on an 8-foot pole. The operator receives instruction from the defense commander. He observes through a loophole or periscope.

The primary use of the trench light is for defensive work to illuminate the foreground in order to detect enemy patrols cutting the entanglements, or to fire on the enemy in case of a general assault.

The trench light has many other uses, such as:

(*a*) Illuminating the site for the construction of a bridge, machine-gun or battery emplacement or any other night construction work.

(*b*) Illuminating the enemy side of a bridge or ford to assist in the protection of it.

(*c*) Furnishing light for loading or unloading men, animals or material at night.

(*d*) The same batteries with smaller lights can be used for the general illumination of the communicating trenches, latrines, command posts, etc.

The location of the lights in a trench or a defensive position is of utmost importance. Improperly located they serve to define exactly, to the enemy, the trace and flanks of the line they are to serve. If allowed to shine too long they furnish excellent aiming points for the enemy's fire.

When properly placed they refuse to the enemy those undulations of the ground which otherwise would permit him to advance his attack, unheard and unseen, to within a few yards of the first trench. By scientific location and operation the lights can often be used to deceive the enemy as to the exact location and extent of the position.

Training.

As the lights are to be *used by the infantry,* each battalion should

be given opportunity to train a squad of men in the handling of the light. This training will consist of learning:

(*a*) The parts of the light, its care and adjustment.
(*b*) The use of the battery, its care and method of attaching wires.
(*c*) Handling the light so as to obtain illumination on the desired object, in the open, through loophole, through periscope.
(*d*) Operation by telephone from the infantry commander.

The officers will need training in selection of positions for the lights and in obtaining co-ordination between adjacent lights. They will be practiced in locating lights and operating them by telephone, buzzer, flash signals or messenger.

In all actual use of the lights at night in problems where no ball ammunition is used, officers or noncommissioned officers should be in the assumed hostile positions both to serve as targets and as observers and critics of the use of the lights.

(C) BATTLEFIELD ILLUMINATION WITH ROCKETS, STAR SHELLS, ILLUMINATING GRENADES AND BOMBS.

All these methods of illumination are propelled from a rifle or mortar high into the air, where they ignite and burn with a brilliant light for 10 to 30 seconds.

The illuminating rifle grenades are no longer in the experimental stage. They are now ready for issue to troops. Each regiment will eventually be given a supply and an annual allowance for use in training.

The advantages of this method of illumination are:

(*a*) The light comes from high in the air, similar to daylight, hence no long shadows. It illuminates the foreground to a distance of 500 yards.
(*b*) With favorable wind or no wind the light can be placed over the desired object without revealing the location of the operator.
(*c*) It requires no special technical troop and no expensive equipment.
(*d*) It is low in cost.

The disadvantages are:

(*a*) With a reverse wind the light may be carried back over the defenders trench and serve the enemy.
(*b*) To overcome this the time of burning must be limited to 10 seconds and more rockets used.
(*c*) The range as a projectile is limited to 200 yards in favorable wind.

In addition to their use for battlefield illumination, colored rockets are used extensively for signaling between infantry and artillery.

Training.

Training in the use of this method of Battlefield Illumination must be similar to that outlined for trench lights. The training combines naturally with all night problems.

Each company should have selected men trained in the use of the rifle illuminating grenades. These men will carry the grenades into action and they will be placed by the company commander and fire their grenades under his orders. The remainder of the company must be trained to quickly pick up and fire at the target when it is illuminated by the light of the grenade. Proper training will effect economy, and obtain maximum effects from each grenade fired.

Flares.

A flare is usually a paper cylinder containing a combustible such as nitrate of potash, sulphur and orpiment or magnesium ribbon, which burns about 1 minute with a brilliant flame. The flare is wrapped in wax paper, it is about 14 inches long 1 inch diameter. At one end is a tin-foil cap covering a tape.

Directions for lighting are printed on the flare. Another method is as follows: Tear the paper away from the heavy end of the flare. Place one end of a piece of time fuse against the end of the flare and pour the powder from a rifle cartridge over these two ends. Wrap with tape or bandage.

They are used for illumination and signaling.

In Defense.

For illumination they are most often used in a pit attached to a trip-wire so that the enemy in advancing toward the entanglement falls over the trip-wire which operates the flare.

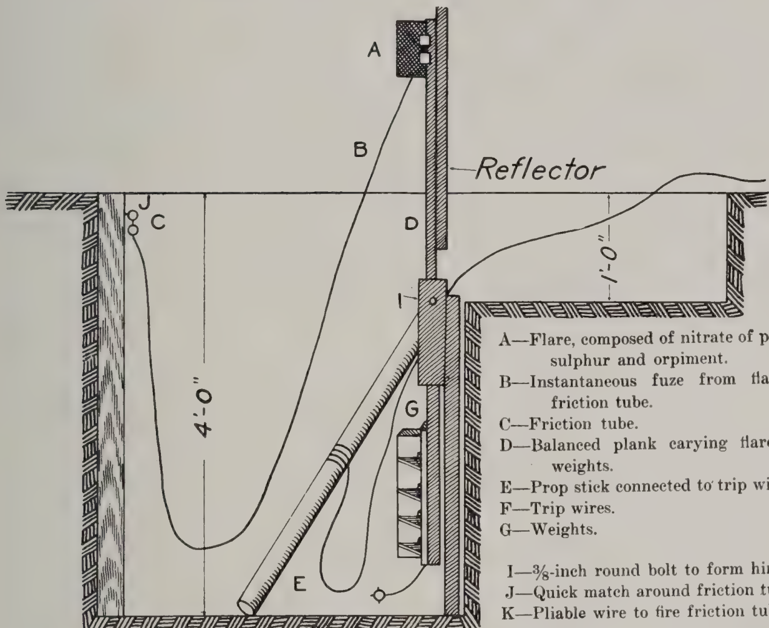
The flare may be lighted by a wire operated in the trench.

Flares take the place of the kerosene torches and bonfires that were formerly employed to illuminate the entanglements.

On Offensive.

Sometimes, when the contact aeroplane observer sounds his horn or otherwise signals to the infantry to disclose the line of advance which they have reached, a flare is lighted. The observer can then signal the artillery to raise or lower the barrage as may appear necessary.

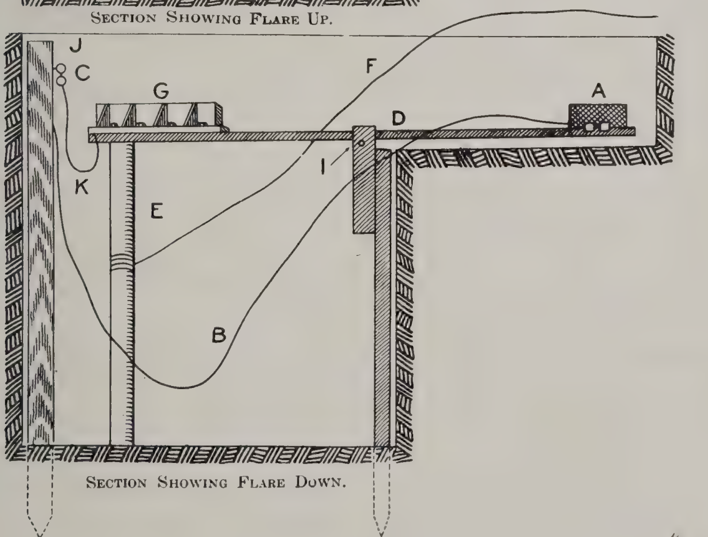
AUTOMATIC FLARE LIGHT AND PIT.



A—Flare, composed of nitrate of potash, sulphur and orpiment.
B—Instantaneous fuze from flare to friction tube.
C—Friction tube.
D—Balanced plank carying flare and weights.
E—Prop stick connected to trip wires.
F—Trip wires.
G—Weights.

I—$\frac{3}{8}$-inch round bolt to form hinge.
J—Quick match around friction tube.
K—Pliable wire to fire friction tube.

Section Showing Flare Up.



Section Showing Flare Down.

The importance of this method of communication used day or night and with or without the time schedule, cannot be overestimated. The success of the assault depends upon the infantry keeping so close to the barrage that the enemy will not have time to man his trenches from the dugouts and cave shelters, after the barrage has lifted and before the attacking infantry reaches the trench. If the infantry fails to disclose its position to the aeroplane observer when called upon to do so, the barrage will either not move forward with the infantry or will move too far ahead of it, causing more casualties in the attack which follows than could possibly have been caused by the enemy discovering the position of the infantry.

Men lighting flares place them in the bottoms of shell holes or other depressions when possible.

Training.

A line of pits should be arranged just in rear of the entanglement with the trip-wire in front of the entanglement.

If time does not permit the use of the pit, the flare with its reflector can be fastened to a stick 4 to 5 feet above the ground with the igniting cap at the base of the stick. A heavy stone trap can be used to give the necessary pull.

One point to be brought out in the training contemplated is the efficiency of the engineers in delivering to the infantry the trench lights and flares in good time and in working order.

The allowances above given are made from recommendation of observers in the European War and may be modified as a result of the training contemplated.

PROBLEMS IN BATTLEFIELD ILLUMINATION

BY

Capt. W. S. DRYSDALE,
Eighth Infantry.

TRAINING OF INFANTRY TO FIRE AT NIGHT AIDED BY ILLUMINATION.

Problem for Infantry.

1. Using indirect fire—

(*a*) Determination of probable effect of infantry fire at night. Sights and auxiliary target lighted.

(*b*) Determination of suitable auxiliary target.

(*c*) Report on other data of interest such as rate of fire, fire units, control of fire at night, necessity for lighting sights, etc.

2. Using direct fire—

Same as above, omitting (*b*).

3. Suitability of Infantry fire for attack at night, foreground lighted.

Problem for Engineers.

1. Determination of most suitable position for searchlight units to light the sights, auxiliary target and foreground for Infantry.

2. Suitability of flares, searchlights or other devices for the purpose of furnishing the necessary illumination for accurate firing of Infantry at night.

3. The proper protection for the lights from hostile fire.

4. Suitability of lights for aiding the Infantry to attack at night with fire.

The problem was tested at night with one company, aided by illuminating bombs furnished from the Engineer train.

Indirect fire was used.

The problem was one in which the hostile firing line (represented by 64 kneeling figures) was almost entirely hidden from view in the under-brush and consequently furnished a very unsatisfactory target. It was 350 yards distance across the valley of the rifle range.

An auxiliary target (a small bush), midway between the firing line and targets was used and a sight setting (readily determined from the new issue field glass) was used that brought the shief of fire into the target.

The auxiliary target being midway between the target and the firing line, the dispersion at the target was exactly equal to the front of the company firing and, although the target was practically invisible, about 70 per cent of the figures were hit, firing 5 rounds per man, firing clip fire.

It is thought the above method would be suitable in a carefully prepared defensive position and the use of an auxiliary target which is unmistakable and distinct, will result in more target hits than firing at the target itself, particularly when that target is indistinct as would most frequently be the case in combat firing, particularly at night.

Interesting and valuable data may be compiled from tests of night firing conducted by different organizations at night that may result in a method of training for night firing that would increase the efficiency of Infantry fire at night.

How France Subsists Her Armies at the Front[1]

Victory, said a soldier, will belong to that one of the adversaries who can hold out a quarter of an hour longer than the other. Victory, the economist will say, will belong to that one of the belligerents who shall have in the last reserve one month's more food than the other. Men, as well as material, must be nourished quickly and for a long time. Munitions for the guns, food for the troops. An army which eats badly, fights badly. An army which no longer eats, no longer fights. No truth has been confirmed more cruelly than has this on several points of the vast theatre of operations in the course of this campaign.

Today, after thirty-one months of a struggle which, though in different degrees for the two opposing parties, has been thirty-one months of profound economic wear and tear, subsistence appears like an engine of war capable of briskly turning the scale, military and diplomatic, in favor of one or the other of the two groups of the people engaged. By means of a foresight rigorous in the extreme, but much to be admired when the history of this war shall be written, our enemies, though deprived of the sea, have, up to the present day, been able to subsist. It seems from many credible indications that they now subsist only with the greatest difficulty, but we, ourselves, in spite of our free coasts, are confronted with the same problem, which calls for tardy measures of wisdom and the complete reorganization of the direction of civil and military supply services.

If with us a proper restriction is placed upon prodigality of food in the interior, our armies will be supplied with provisions up to the end of the war however it may be prolonged. We can regulate the civil supply where almost nothing had been foreseen; but military subsistence, based on the number of rations required for a certain effective force, can only be slightly modified in its application. The system adopted before mobilization and tested for two

[1]Translated, by permission, from *L'Illustration,* March 10, 1917, by Col. W. R. Livermore, U. S. Army.

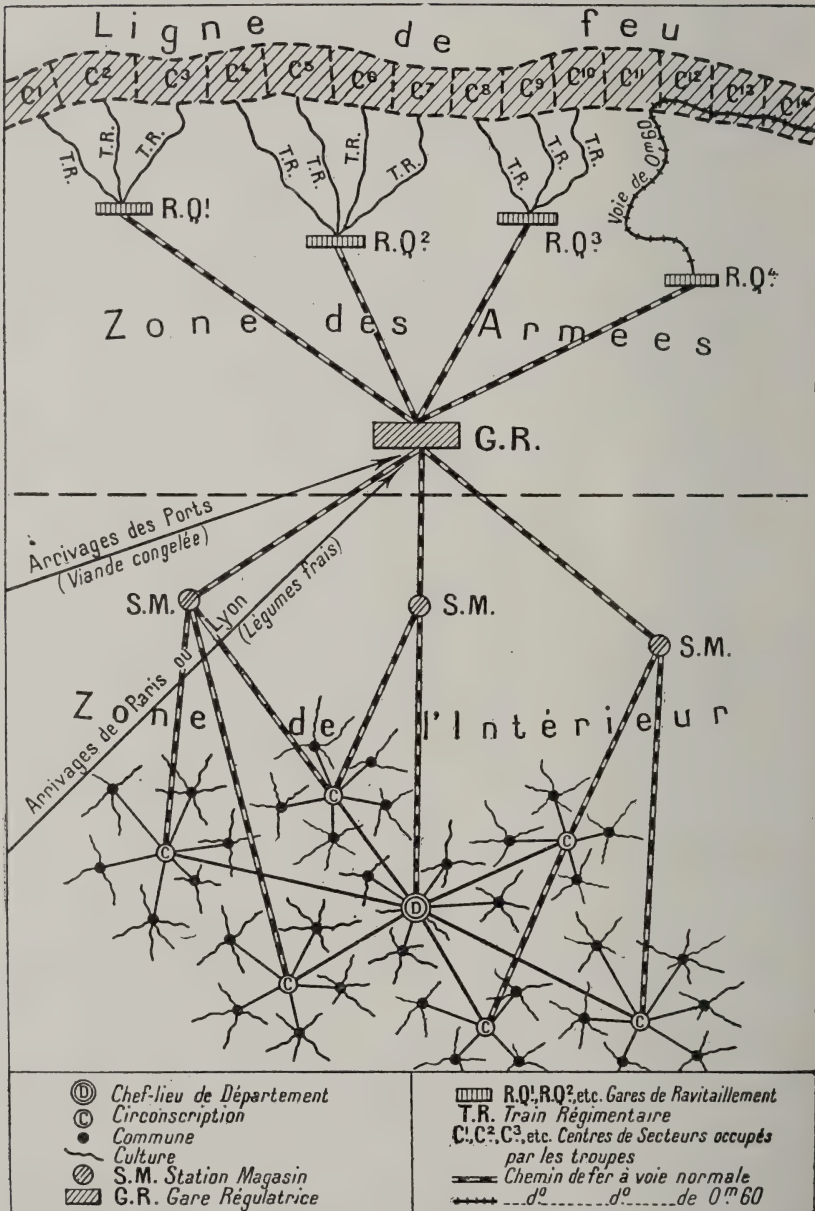
years and a half of war, has otherwise given satisfactory results; and one neither would nor could transform this organism which has adapted itself to the exigencies of the warfare of the present day.

I. SUBSISTENCE FROM THE LAND.

The time has passed when armies in the field can count upon living entirely off the land which they traverse or occupy. On that same area where formerly an army of 30,000 men supported its scattered battalions, hundreds of thousands of men, no longer for days, for weeks, or for months, but now for years, are there maneuvered, cantoned or intrenched. The inhabitant no longer feeds the soldier; but it sometimes happens that the soldier is forced to feed the inhabitant, thus completely transforming the economic exigencies of warfare.

Subsistence of troops in the field was organized in time of peace. It was minutely provided for in the plan for mobilization. Food for the men; forage for the horses; supplies for heating and lighting; coal, wood, petroleum, solidified alcohol, and candles should regularly arrive in quantities sufficient for all the troops on the march, the units in cantonment, the battalions in line, and for all the elements resting or fighting, whatever the time, the place, the difficulties that may result from conditions favorable or unfavorable. Hence a vast problem to be solved immediately, in figures always exact in spite of the fluctuating and unknown data. Let us say at once that up to to-day this problem has been solved at the best excepting that at first in rare and inevitable exceptions when the movements were rapid, and in certain actions where the artillery barrage could not be forced, provisions in the broadest sense of the term, have always arrived at their destination in time and in sufficient quantities.

As far as possible, troops should, for their supplies, make use of the local resources. This is an old principle which is written at the head of the regulations for subsistence in the field; but in practice and from the beginning of a war, when the regions traversed still have all the resources of the land at their disposal, the local resources have only a complementary value, and are hardly ever sufficient. We must consider that when a war has lasted for more than thirty months, these immediate resources become not a negligible, but a negative quantity, in estimating the effective supply. The only reservoir on which we can count, or on which we ought to



ZONE OF THE ARMIES

Imports from the sea, frozen meat
Imports from Paris or Lyons, fresh vegetables
0.60-gauge railway

ZONE OF THE INTERIOR

Chief town of Department
Circumscription
Commune
Cultivated field
Station magazine
Station for making up trains
Supply stations
Regimental train
Centers of Sectors occupied by the troops
Railway of standard gauge

count, is that in the rear; the harvests of the soil of all France, and the proceeds of the nation's live stock, completed by the importations from the colonies, from allies and above all from neutral goods flowing daily into the ports along our coast. The complex problem of the importations aggravated by the difficulties due to the state of war; advance in freight, limitation of the means of transport, crises in coal; and torpedoing of the trains, will not be treated here. We will simply say that imported supplies, from the time they are stored on our territory, follow the same rules as the native supplies in all that concerns their maintenance, their transformation, and their itinerary to the front.

II. DEMAND AND SUPPLY.

Up to these very recent times, there has been attached, either to the office of the Ministry of War, or to that of a sub-secretary of the Intendance (department of pay, subsistence, transportation, etc.), a central branch "*Inspection generale de ravitaillement,*" which, at the levy of military provisions, has presided over the collection of the natural resources, and of the distribution, between the front and the zone in the rear, of imported supplies and of millions of hundred weights of wheat, potatoes, oats, straw and forage; of hundreds of thousands of hundred weights of dried vegetables, of dough and fresh vegetables; of dozens of thousands of hundred weights of salt, of sugar, of coffee, of bacon; of the million cattle and of the four million and a half hectoliters of wine, which are annually required (on the basis of the normal ration) for supplying the depots of the interior and the armies in the field.

The total quota, to demand from our soil, is based on the total number of effectives to be provided for, and is divided among the departments according to the importance of their farming land, and on the indications of the agricultural statistics of the preceding years. At the chief town of each department there is a *Comité departmental de ravitaillement* (departmental committee of supply), presided over by the prefect who names its civil members, and one of whom is the military sub-intendant, charged with the local direction of the subsistence department. This committee discusses the assessment and the rate of prices fixed by the minister and, if necessary, demands the reduction of one and the increase of others, after which he proceeds to the distribution of the quota confirmed or reduced, as finally determined between the *conscription de ravitaillement* of the department which was fixed in time of

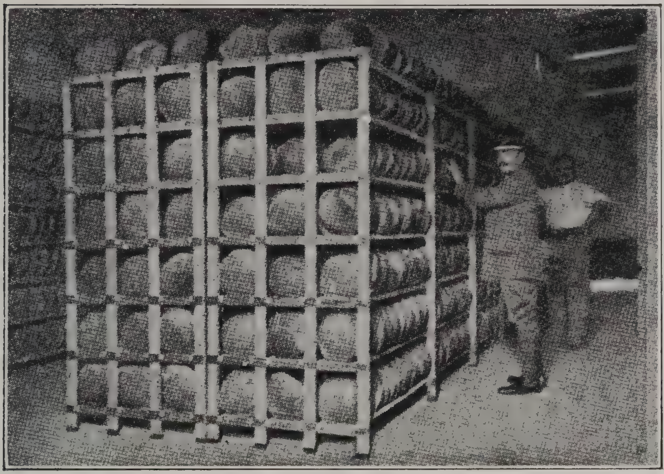
peace and is not necessarily the same as the administrative conscriptions, sub-prefectures or chief town of the canton. The important thing is that in the *conscription* there should be a *gare* (railroad station) well cleared so that there the shipments of grain, cattle and forage may be clearly assured.

In each *Circonscription* there is a *commission de ravitaillement (or de-reception)* whose president is a member of the departmental committee and who proceeds to a new distribution of the quota among the *communes.* Finally in each *commune* the *municipalité* (town council) makes a final distribution among the farms of its territory indicated by the capillary lines of our sketch. Of course, the *chef-lieu* (chief town) is, in itself, a *circonscription de ravitaillement,* and has its own quota to distribute in its own environment. Such is the principle. It is very simple indeed as a principle. The difficulties begin only with the application.

III. INTENDANCE, HUSBANDRY AND COMMERCE.

If, indeed, even the quota of the department has been accepted without reservation or protest by the committee assembled at the chief town, or even if the presidents of the commissions are in accord about the distribution among their respective *circonscriptions,* it rarely happens that the distribution among the *communes* does not encounter much resistance.

The farmers, as a rule, do not care to sell to the Intendance. The considerable quantities to be levied from the harvests, or herds of cattle, for the wants of the army diminish the supply and increase the demand. As soon as the prices for government purchases, for cash, have been fixed by the minister, the selling prices in private transactions at once jump above these fixed prices, so that it has been necessary to have to resort to a tax on the retail trade. Now, the farmers will almost always receive higher prices from the merchant than from the military administration, however remunerative, in itself, may be the price offered by the latter. Moreover, he will prefer, at the same price, or even at a lower price, to deal with the merchant whom he knows, who supports him in time of peace, who occasionally makes advances, and with whom he will have new dealings when quiet times return. Then, between the *Intendance* and the husbandry, commerce intervenes, "the middle man," who must always be considered and encountered, as it is for him that the producer will always be tempted to reserve the greatest part of his harvest. . . .



Pantry in a Station-Magazine. (S. M.)

Distribution of the *pinard*.

We see, then, how delicate and hard is the task of the president of the commission representing the *Intendance* in his relations with the mayors, the farmers, or the breeders, who are counselled and tempted by the middle men. . . .

IV. PROVISIONS ARE MOVED AND TRANSFORMED IN THE INTERIOR.

After having been gathered in the fields and pastures by the innumerable capillaries shown on our diagram the provisions begin the voyage, which, in many days' march, should bring them to the front as far as the trenches of the first line.

However limited the means of transportation may be, they never fail for the military *subsistence.* This always has the right of way, on the days fixed by the departmental committee in accord with the *Intendance,* the animals, or the goods are assembled at the *gares* of the chief towns of *circonscription* where they are examined by the president of the commission, assisted by an expert, in the presence of an officer. According, as the provisions are destined for the troops of the depots or those in the field, they are directed toward the bakeries and forage parks, or toward the *Station-Magasins* (station magazines) (S. M.), respectively.

The *Stations-Magasins* . . . situated in the interior zone, are vast *entrepots* where, as a rule, are gathered everything needed to feed, heat and light an army in the field. Whole herds of cattle wait to be distributed to the parts on the front. On the spot, soldier butchers sacrifice by hundreds swine that will be sent to our soldiers in the form of bacon in strips, of fillet, of pies, and of tripe. The straw and hay, of which the volume has been reduced by pressure to one-fourth or fifth, come in balls of 40 to 60 kilos, and are piled in immense stacks. Wheat, which has already been transformed into flour by the great mills of the region, comes to feed the war bakeries occupied night and day in making that bread lightly twice-baked, and easily preserved, which at the front is eaten indiscriminately by officers and men. To the *Stations-Magasins* are forwarded also thousands of cases of preserved beef and pork, dried vegetables and all the little accessory food, of which, especially sugar, coffee and tea, come in enormous quantities, directly from the seaports.

The replenishing is assured by the daily afflux from the *capillaries* of the interior supply, and by the further contributions from the maritime supply.

V. THE PROVISIONS GO TO THE FRONT.

. . . Every day the *Stations-Magasins* make up complete trains of cars containing the number of rations required for the *Gare Regulatrices* which they should feed. The cars, as soon as loaded, packed and ticketed, are directed to the G. R., which receives in addition: 1st, frozen meat coming directly from the seaports; 2d, all the fresh vegetables, cabbages, beets, peas, and salads, which are brought from two great centers of reunion of green groceries, Paris, La Villete and Lyons. After choosing the cars sent by the

One of the platforms of a station-magasin: unloading wagons of flour.

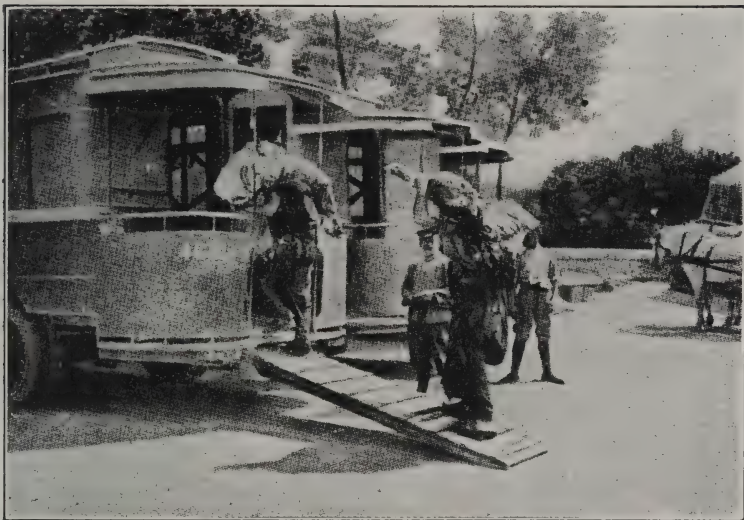
S. M., by the seaports, and by the centers, Paris and Lyons, new packages are formed, each containing the commodities of all kinds required for each of the *gares de ravitaillement,* where the divisions in the field are supplied. Almost everywhere, the regimental cars loaded with cart loads of provisions may come to search directly for provisions at the *gare* installed at some kilometers from the firing line. . . . Finally, it must be noted that in the great number of sectors it has been possible to build little railroads with a gauge of 0.60 meter, which take the place of the regimental carriages, take the provisions to the *gare de ravitaillement,* or near it, and convey them either in the open or by the tunnels picturesquely

baptized by the "*poilus*" (hairy ones, *i. e.*, enlisted men), the "Saint Gothard," the "Metro," the "Simplon," "Nord-Sud," etc., as far as the interior of the lines.

But the *gares de ravitaillement* are, nevertheless, the centers whereby the *antennae* of the regimental trains, or of the 0.60 m. gauge roads, the troops come for supplies. These *gares* have been regulated especially for their functions in war. A number of them detected and bombarded have had to be abandoned, but they have been seen to revive 1,000 or 1,500 meters further off in the middle of a field, on the edge of a forest, on the side of a hill, ready to disappear again according to circumstances, to pop up afterwards, to retreat, or to advance according to the movements of the troops.

VI. THE MARKET UNDER THE CANNON.

Nothing is more animated, agitated and humming than those improvised *gares* where, in the picturesque gravity of war, at the sound of the cannon, menaced by the enemy's aircraft, and in range of their heavy artillery, there is daily held the market, if it may be so called, of the units in the field, all along the wooden platform thrown over the mud of the fields, the regimental wagons are aligned. With the hooped and rounded covers they seem like the chariots of the war, driven by the mediaeval stagers with helmets of iron and girded at the waist in a cope of sheepskin. The modern note reappears when our old Parisian auto buses arrive, rapid and always solid, and are brought up by their old conductors who have been duly mobilized. They carry to the troops the fresh meats, the cattle slaughtered in the cattle-pens of the divisions, which, with frozen meat dispatched from the seaports or hog products sent from the magazine stations constitute the meat ration for the troops. The subsistence officers go and come along the train which is unloaded. They examine the quality of the commodities, the fresh vegetables, the forage, which is delivered to them; if need be, they discuss with the representatives of the Intendance (the contractors). Then sympathetic groups are formed. Staff officers pass. They exchange news or gossip a little; officers on leave report the echoes of the capital, and have many amusing tableaux in "unexpected of war." A hairy wagoner lets his locks wave, provoking inextricable embarrassment with the teams. The men swear at this half savage who, dumbfounded, drops a book. I picked up the old volume. This wagoner was reading Suetonius in the original text. A little further on a slim officer, rosy, chubby faced, daintily



Loading fresh meat into the old Parisian auto buses.

Transport of Supplies by a "*tortillard*" on a 60 cm. railway.

dressed, gracefully capped, with shining spurs, passes by, trailing his horse behind him. He stops before a wagonload of stripped cabbages and with solemn gestures refuses to take the volume. This little lieutenant well waxed, with a sweet expression and tranquil manner, is the Abbe M., Professor in the Seminary of the South, transmuted by the accidents of war to a commissary officer of a squad of litter bearers. From the here and there *gendarmes,* distinguished by the white grenades on their caps, police the avenues of approach under the direction of the field officer commanding the cavalry of the regimental trains. Sometimes, on the road 300 meters off, a confiscated auto pops up, no one knows whence, and bruskly stopped, a helmet shows itself at the door; a carriage which is going at a great rate is hailed and halted, the driver, when challenged, gives his name and indicates his unit; he will suffer for having made his carriage go at a gallop; he has just met the Provost of the Army Corps, charged with the policing of the roads. The Provost is the terror of everything on wheels in the sector. He appears instantly out of a forest or a fog, as a bomb falls from the heavens. The "*poilus*" (hairy ones) call him "*le taube*" (the aeroplane). . . .

The market is over. Little by little the teams, in long files, move off by the roads of approach. The platform is empty. . . . The Intendance departs; the *gendarmes,* in their turn, disappear; and the *gare,* abandoned and again deserted, becomes silent, and sleeps until the break of the following day.

VII. PROVISIONS GO TO THE FIRING LINE.

And now, by the military routes which the cannon watches, or by the sinuous path of the "*tortillards*" the provisions move on towards the troop under fire. Each of the regimental trains, by motor or by horse, rejoins the center which its regiment occupies in the sector and (leaving the forage at the cantonments where the carriages are put in the stable) deposits the provisions for men at a point fixed for the distribution by the commissary corporals of the companies, after which these provisions are distributed among the kitchens or where the cooks make the best disposition of them that they can, according to their individual genius. It appertains to the commandants of the centers to watch and see that the food always arrives warm at every element of the line, and up to each of the advance posts, sometimes to 10 meters from the enemy.

Train of small trucks hauled by a horse.

An ingenious improvised plant. Trucks rolling toward the firing line on two wires.

There are, nevertheless, companies whose provisions for the day do not arrive at their destinations. An engagement begins. The troops have made a bound to the front. They install themselves in the trench facing them. Or rather the center is bombarded; the men take refuge at the bottom of their shelters and *barrage* fire cuts off all communication between the lines. The *boyaux* are destroyed; the tunnels are obstructed; the works are completely isolated and have no longer, with the other fronts, anything but the uncertain and fragile *liaison* of the telephone. They must be fed, however, whether marching or immobilized. Then it is that the men have recourse to the reserve provisions: war bread (biscuit), preserved meat, salted soup, chocolate, sugar, and coffee in tablets. There should be provisions for two days in the sack and one in the company wagon if the troops are moving, or in the reserve depots of each company (even in the dugouts of the sector) if the troops remain in their lines. Let us add that the maintenance of these provisions is especially difficult in certain centers which are infested by rats that penetrate the men's quarters and in those that are very moist, for the metal itself of the water-tight cases in which bread, coffee, soup, sugar and chocolate are kept, finally becomes porous. The supply officers of the regiment should scrupulously watch the replacement of the damaged provisions as well as the proper care of the water supply. To their provisions for the sectors the Germans add boxes of mineral water bottles, which are easily preserved, and which are manipulated and removed as easily as boxes of preserves. Their example could be followed; on the other hand, it would not be very expensive to protect the provisions from rats by means of a light metallic envelope. All the commandants of the centers invaded by the rodents beg for this indispensible means of protection. The intendants have made propositions on this subject. Their realizations should be easy. It would be important that they should be rapid if the provisions in the sack, the supreme reserve of the human combustible, should always be complete and remain serviceable and edible at the immediate disposition of the "*poilus*," deprived of every other resource.

Of course in this study, necessarily limited, we have only indicated the most general lines of supply in the interior as well as in the field. There are cases in which the general supply should be completed by individual enterprise. There was the retreat on the Marne, followed by the victorious advance; there were the agonies

of Verdun, and the bounds on the Somme; there was the intensive utilization of the autos, the employment of the *Bourriquets* (little asses); there were especially, the audacious ingenuity and the heroism, obscure but efficacious, and sometimes decisive, of all the brave men who, through the fire of the barrage, have revictualled their glorious comrades even into their shell holes; but this is anecdotal history, and we turn, for details, to the roll of honor of the citations of this war.

VIII. THE NECESSARY AND THE SUPERFLUOUS.

We have just seen how, after certain stages and some back turnings in the course of an itinerary, often harassed and almost always picturesque, the necessary victuals reach the "*poilu.*" But a necessity clearly comprehended always includes a little superfluity. The provisions for the day, considered by the regulations as indispensible for the troops in the field—after taking account of certain extras exceptional and justified by the circumstances of the war—are composed of 650 grammes of twice-cooked bread, of 450 grammes of meat, fresh or frozen, with 30 grammes of bacon, 100 grammes of dried vegetables, rice, beans, lentils, dough or potatoes for which preserves may be substituted; also in variable quantities, green vegetables (from 300 to 400 grammes), bought by the units of the Intendance at the fixed premium of 0.24 fr., which is allowed them per man and per day, and which allows to the commissary some initiative in varying and completing the menus.

Moreover, our soldiers handle daily a demilitre of wine, 36 grammes of roast coffee and 48 grammes of sugar. To this must be added 20 grammes of tobacco, 8 grammes of soap, 1 kilogram of wood or 600 grammes of coal, 4 grammes of candles which are increased by 25 grammes when the men are in the sunken dugouts, and finally 50 matches a fortnight; usually those bad matches which it is impossible to light on the gray boxes.

So much is indispensible. As to the superfluous, that is only granted by the Minister on the 1st of January and the 14th of July. As for his New Year's gifts, the "*poilu*" receives one ration of champagne (?) wine, some ham, 2 oranges, biscuits, and 1 cigar. A very pretty feast on paper, but in practice the oranges arrive not always in time, or in very good condition; the dry biscuits are moderately appreciated; the administrative cigar is not worth a good pipe, and as for the "fizz," apart from its being often inferior to the *pinard* which they habitually receive, it no longer has any

relish for the men since they are obliged to return not only the bottles but *even the corks.* Return the corks of champagne! Run after them in the *cagnas,* in the deep dugouts, the advance-post trenches! . . .

The system of co-operation existed already before the beginning of hostilities, in many corps. There is now a co-operative for each division with all the indispensable annexes which sell sweet-meats to the "*poilus*" up to 300 meters from the enemy. They are at once groceries, tobacco stands and bazaars where one finds even articles of refined toilet and fine letter paper to write to their godmothers.

The Madsen and Bergmann, 1915, Models of Automatic Rifles Used by the German Infantry.

[From reliable sources.]

(a) The Automatic Rifle, Madsen, Forms the Armament of the Rifle Battalions.

(b) The Automatic Rifle, Bergmann, 1915, Also Known as a Light Machine-gun, is the Arm of Recently Identified Light Machine-Gun Sections.

Method of Using the Madsen Automatic Rifle.

Insert the clip by tipping it so that the catch *(a)* engages in the slot (A); twist it gently around (A) so as to hook *(b)* under the loading hook and disengage the Clip Catch.

Load by pulling back the cocking-lever (on the right side) until the firing-pin and the cocking-stud catch. Then bring the cocking-lever back to its first position. Pull the trigger, taking care to release the safety (by turning it downwards).

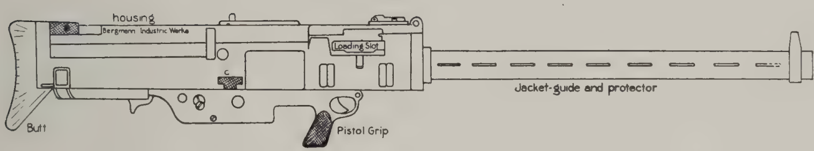
The sketch illustrating this arm was made from a piece taken from an enemy plane which was brought down.

It is probable that the infantry arm has been subjected to the following modifications:

(1) A support, similar to that of the Madsen Automatic rifle, has been fitted on the end of the barrel;

(2) Elimination of the rear portion of the trigger-guard, designed solely to fasten the arm onto an aeroplane.

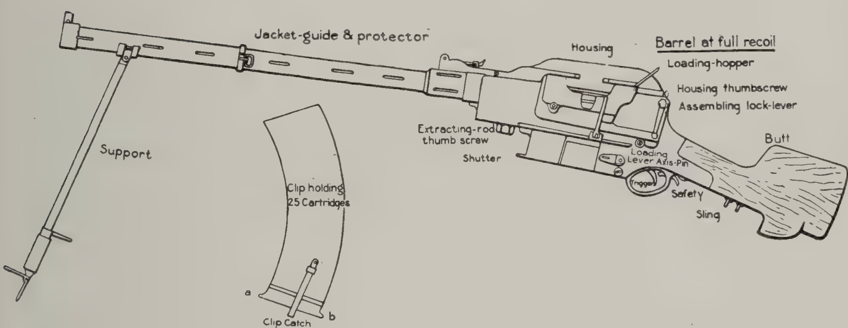
AUTOMATIC RIFLE "BERGMANN" 1915



Inscription on housing
L.M.G. 15
22

Light Machine Gun arm of the
Leichte M.G. Trupps

MADSEN AUTOMATIC RIFLE



Organization and Duties for Trench Fighting[1]

BY

Capts. O. N. SOLBERT, *C. of E., U.S.A.*, and GEORGE BERTRAND, *French Army.*

I. SPECIALISTS.

1. The exigencies of modern warfare, especially trench warfare, have developed new infantry weapons. As there are several kinds of these weapons to each infantry company, the men detailed to handle them must be trained as specialists.

The weapons are:

Hand-grenades,
Rifle-grenades,
Automatic-machine rifles,
Rifles.

The men who use these weapons are respectively known as

Hand-grenadiers,
Rifle-grenadiers,
A. M. R. crews,
Riflemen.

2. As a consequence of these new weapons, a company is now organized on a basis of these specialists. Our infantry company is patterned on that of the French, the only difference being in the number of specialists. Each of the four platoons of our company contains the same number of specialists; each platoon is divided into four sections of specialists.

Organization of Our New Company.

One lieutenant (1st and 4th platoons under 1st lieutenants; 2d and 3d platoons under 2d lieutenants).

One sergeant (second in command, assistant to platoon commander).

1st Section,	22 men,
2d Section,	12 men,
3rd Section,	12 men,
4th Section,	11 men.
Total	57 men × 4 = 228 men.

224 rifles, 664 pistols, 8 automatic rifles.

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[1] The first three of a series of twelve lectures given by Capts. Solbert and Bertrand on "Tactics and Duties of Small Units in Trench Fighting."

Platoon—1st Section—Hand and Rifle Grenadiers.

1 Sergeant, pistol and rifle,
3 Corporals, pistol and rifle,
6 Privates, 1st class, all with rifles, two of them with pistols,
12 Privates.
—
22

Platoon—2d and 3d Sections—Riflemen.

2 Corporals, rifle and pistol,
3 Privates, 1st class, rifle,
7 Privates, rifle.
—
12

Platoon—4th Section—Automatic Riflemen.

1 Sergeant, pistol and rifle,
1 Corporal, pistol and rifle,
3 Privates, 1st class (automatic-rifle gunners, including 1 extra),
6 Privates, rifle.
—
11

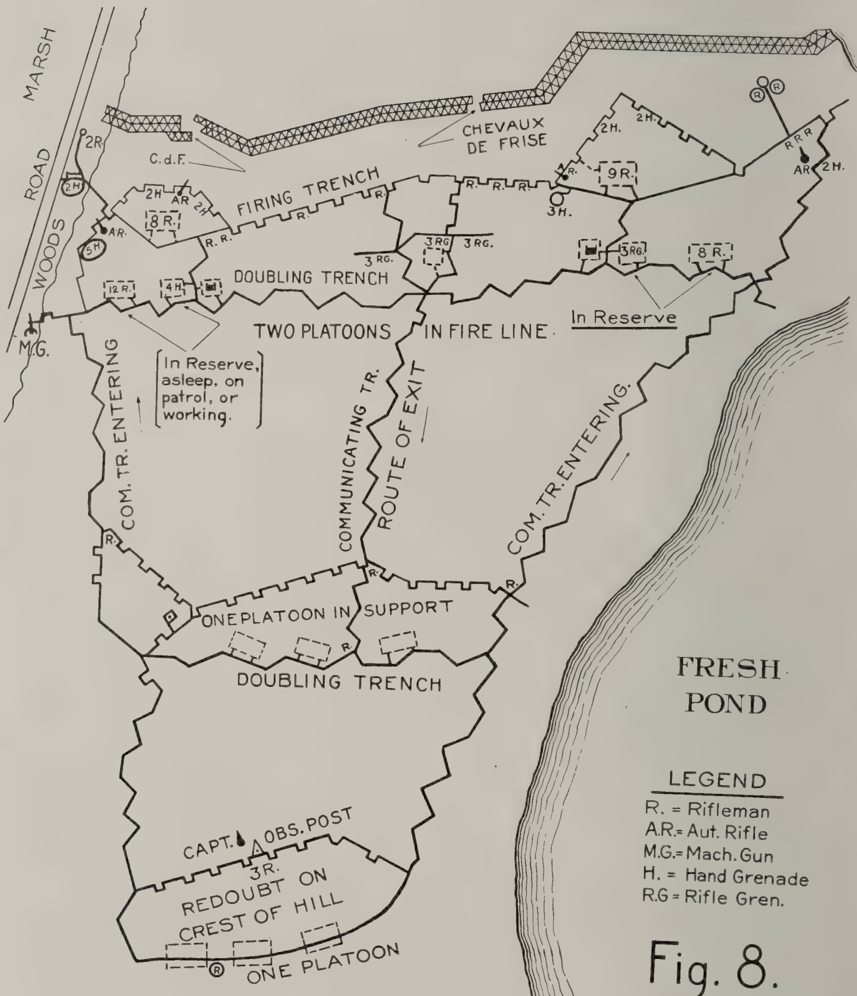
Officers.

1 Captain,
3 First Lieutenants,
2 Second Lieutenants.
—
6

3. The platoon is the self-contained unit with the proper proportion of all the different kinds of specialists for the assault. The reason for this is that the platoon is the largest unit that one leader can control in combat. For this reason the four platoons are alike and interchangeable.

4. Although it is true that the specialists are particularly trained with their own weapons, all men of the company are first trained as riflemen. All specialists carry rifles and if for any reason they cannot use their special weapon they become immediately riflemen. Also every man is trained in hand-grenade throwing. This makes it possible to fill gaps in the specialists' ranks from the riflemen. Some men also, say to the number of the A. M. R. crews, must be trained to operate the automatic machine rifles.

5. The remaining supernumeraries of the company, such as mess and supply sergeants, mechanics, cooks, buglers, etc., do not march with the company in maneuver or combat formations. Some of the above supernumeraries will be found in the captain's headquarters group, such as the liaison agents from the platoons, orderlies, buglers



MARSH
ROAD
WOODS
M.G.
CHEVAUX DE FRISE
C.d.F.
FIRING TRENCH
DOUBLING TRENCH
TWO PLATOONS IN FIRE LINE
In Reserve
In Reserve, asleep, on patrol, or working.
COM. TR. ENTERING
COMMUNICATING TR.
ROUTE OF EXIT
COM. TR. ENTERING
ONE PLATOON IN SUPPORT
DOUBLING TRENCH
CAPT.
OBS. POST
3R.
REDOUBT ON CREST OF HILL
ONE PLATOON
FRESH POND
LEGEND
R. = Rifleman
A.R.= Aut. Rifle
M.G.= Mach. Gun
H. = Hand Grenade
R.G = Rifle Gren.

Fig. 8.

and observers. Mess and supply sergeants, cooks, etc., remain with the regimental train in rear with the kitchen behind the artillery positions. The tactical group of the captain live in an adjoining dugout to that of their chief in the sector. In the fight these latter are used as messengers or observers.

II. USE OF SPECIALISTS.

1. The following table shows the evolution of infantry armament since the beginning of the war:

	At beginning of war.
Rifle and bayonet	Nearly total personnel
Hand-grenades	Nil
Rifle-grenade guns	Nil
Automatic rifles	Nil

	Present time, U. S.
Grenadiers, per company	48
Grenadiers, per company	24
A. M. R.	8

Outside the company is the 37 mm. gun, in the batallion, trench mortars, and engines, permanent equipment of the trenches.

Use in the Defensive:

Hand Grenades. Hand grenades are used to produce a short-range barrage at a distance of about 30 yards in front of the trenches. For this purpose one grenade thrower is required for from 10 to 16 yards of frontage.

They are also employed to establish centers of resistance to protect important features of the lines, such as salient, machine-gun or automatic-rifle posts, command posts, listening posts, etc.

They are used to defend barricades in a communicating trench. In this latter case the grenades may be thrown from a special bombing post established for the purpose, or from an adjoining trench.

Rifle Grenades. Rifle grenades are employed to establish a barrage at a greater range than that of the hand grenade, being used up to as great a distance as 300 yards (U. S.). The great advantage of the rifle-grenade barrage is that it is under the control of the platoon leader and can be called into service automatically, which is not true of the artillery barrage.

Several grenade-rifles concentrated on a trench will stop hand-grenade throwing from the same. Rifle grenades are usually shot from the doubling or cover trench immediately in rear of the fire trench.

Automatic Machine Rifles. In the defensive the A. M. R.'s are employed to obtain flanking fire usually from the firing line, but may be used in the doubling trench and sometimes in shell holes out in front. In interior fighting they are used to cover stretches of communicating trenches after the enemy has penetrated.

Riflemen. The riflemen are placed in the intervals between the squads of specialists in the firing line. They are also used as snipers and as sentinels. These sentinels are not to be confused with watchers, who may or may not carry rifles.

For example, the posts of the specialists in a sector on the defensive are shown in Fig. 8.

Use in the Offensive:

Hand Grenades. In the offensive hand grenades are used to reach the enemy under cover in trenches, etc., by high angle throwing. It is an excellent weapon to clear out the trenches that the assaulting column is advancing against. The H. G. and the R. G. break the resistance, so to speak, of the line that the attack is to capture, and the assaulting troops are to occupy and hold. The place of the hand grenadiers in the assaulting column is seen in Fig. 7.

The hand grenade is the principal weapon in trench combat, that is, to progress laterally and in depth in the trenches after a breach has been made at one point, as every foot of trench has to be fought for. Each section of trench, between traverses, is cleared of the enemy by throwing H. G. into it. It is then occupied and the next section cleared in a similar manner.

In a raid on the enemy's position hand grenades are used to clear up the particular trenches before the raiding party jump into them. This will be taken up in detail in a later lecture.

Rifle Grenades. The rifle grenade in the offensive is employed similarly to the hand grenade to reach an enemy under cover, but at a greater distance.

It is used to help reduce all nests of resistance that the assaulting infantry run up against and when the artillery barrage is not obtainable.

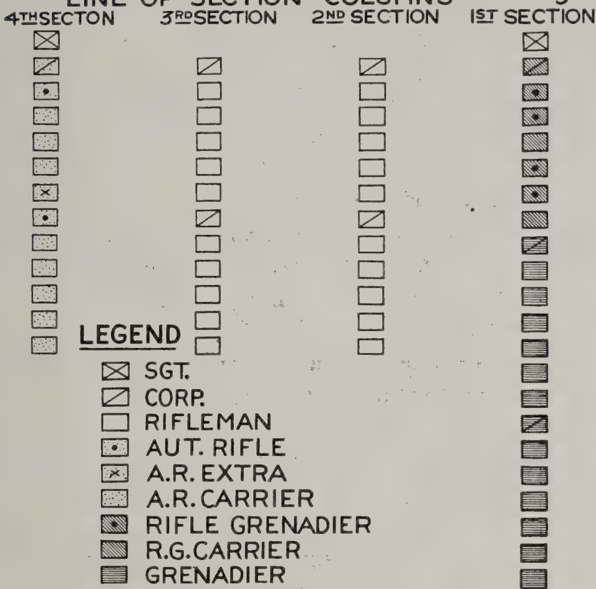
They may be used as a barrage to cut off the retreat of a small group of the enemy that is being attacked in front.

It is very useful against the counter-attack, especially before the machine guns can come up and the artillery barrage obtained.

The A. M. R. The A. M. R., with its great mobility and ease of

INITIAL FORMATION OF THE PLATOON
LINE OF SECTION COLUMNS

Fig. 1



PLATOON IN DOUBLE LINE OF SECTION COLUMNS

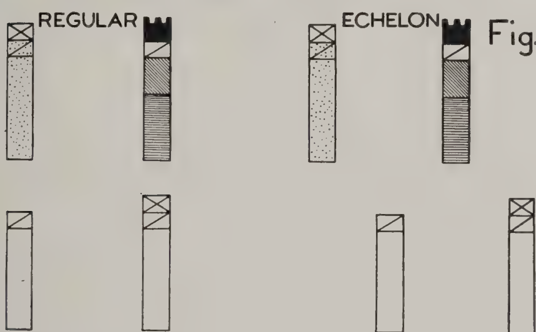


Fig. 2.

control, makes it possible to carry this weapon in the assault and to be used immediately the wave is halted for any reason. In this connection, it can be instantly employed against a nest of resistance.

It is used in the assault to protect the flanks of the assaulting waves, especially when stopped.

As the A. M. R.'s are brought up in the first wave, they are immediately available against counter-attacks upon the captured position. In a similar manner they are employed to hold ground gained until an artillery barrage can be obtained to support it and before the machine guns come up.

The Riflemen. The riflemen, with bayonets fixed, do the necessary fighting in the interior of the enemy's position. As was stated before, the H. G. and the R. G. break the enemy's resistance and the riflemen do the hand-to-hand fighting required to occupy the objective lines of trenches.

To make a little résumé, we may say that the best results will be obtained by the proper combination of all of these weapons. The low trajectory weapons (rifle, A. M. R., H. G. and the 37 mm. gun) concentrate on everything and show above the trenches, while the high angle missiles (H. G. and R. G.) seek out the enemy under cover. The riflemen complete the success of the specialists by rushing forward and occupying the enemy's position and fighting hand-to-hand for it if necessary.

III. FORMATIONS FOR MANEUVERING THIS RESULTANT COMPANY OF SPECIALISTS.

(Formation of the Platoon.)

1. *Initial Formation.* (Fig. 1.) The initial formation of the platoon in sections of specialists as per diagram is almost self-explanatory. Each group of specialists is together under the control of its leader ready for any maneuver.

The platoon is the attacking unit because it contains all the specialists required for the assault. The frontage of an offensive is composed of a series of platoons, each with a definite objective, and each with reinforcing platoons in depth following.

All other formations, whether for combat or ordinary march maneuvers, are based upon this initial formation.

2. *Close Order and March Formation.* From the initial formation we pass to the closed order formations, used for parade, roll call, or the march.

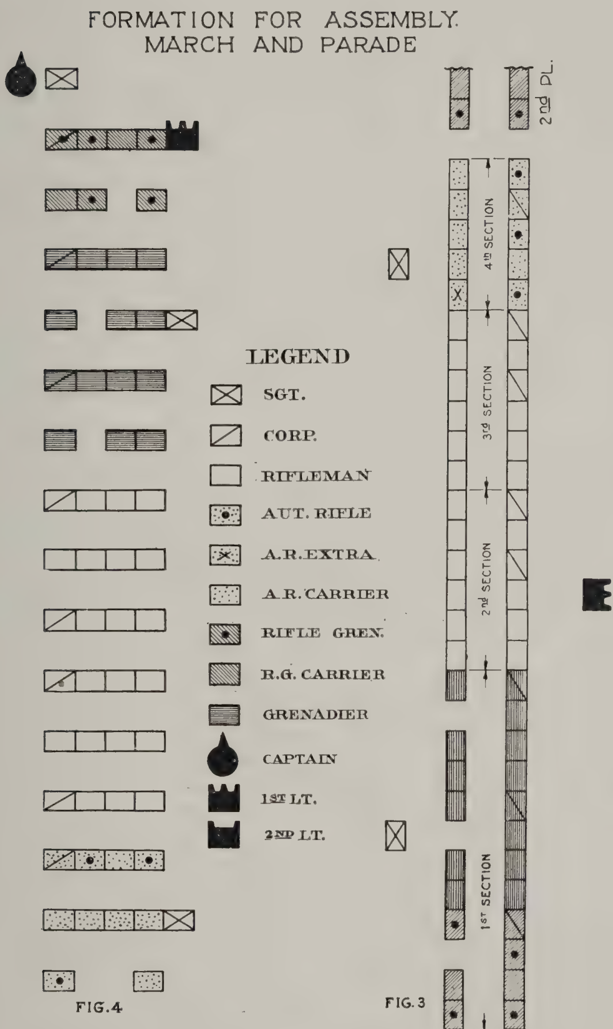


FIG. 4

COMPANY OR PLATOON
IN COLUMN OF FOURS

FIG. 3

COMPANY OR PLATOON
IN LINE

(*a*) First we have the company in line (Fig. 3), which is the habitual formation for assembly.

(*b*) From the company in line is formed a column of fours (Fig. 4) for marching. The squads that are complete execute "squads right or left," while the remaining odd number of specialists in any section execute the easiest movement to bring them into columns of four, sometimes with blank files, behind the rest of their section.

3. Approach March. The "approach march" is the name given to the formations that the platoon in section columns takes up to minimize casualties while crossing the zone of artillery fire.

The formations of approach march are taken up only under the conditions of *open warfare,* or, in the case of *reinforcements* following up an attack.

These formations may be in "Line of Section Columns" or "Double Line of Section Columns" (Figs. 2, 5 and 6). In the first case, each section may be in single file or in double column; or again the first and fourth platoon section may be in double column and the second and third sections in single file. In the "Double Line of Section Columns" any of the formations in the diagrams may be taken up, depending upon circumstances.

The intervals between sections are variable, but usually the interval is such as to give room for the proper development into line of skirmishers.

4. Skirmishers. The formation of skirmishers is not taken up for the assault, but under similar conditions as that of the approach march, that is, for *open warfare* and for the advance of the *reinforcing platoons* behind an attack.

To form the skirmish line, each section column simply deploys into line, each man going either right or left front into line from the regular formation of double line of section column.

If you will inspect the figure, you see that this deployment into skirmish line gives practically the type of formation of the first reinforcing platoon in the assaulting column (Fig. 7).

5. Assaulting Formations. (Fig. 7.) In the attack the platoon forms and goes forward in waves. A wave is not one line of men, but is composed usually of two or three lines.

The composition of the lines of the wave depends upon the duties and functions of the different specialists during the attack. Let us recapitulate the functions of the specialists in order to show the reason for their positions in the first assaulting wave.

COMPANY FORMATIONS
FOR MANOEUVRE

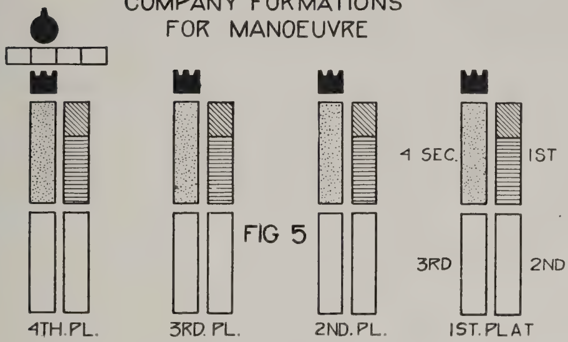


FIG 5

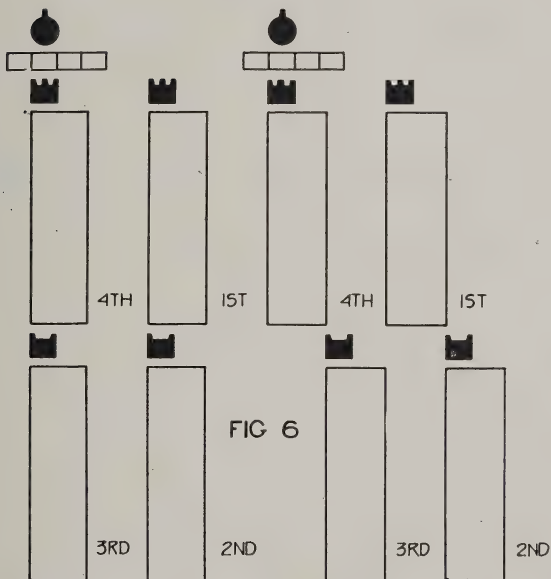


FIG 6

The First Line of the First Assaulting Wave. Here we have the hand-grenadiers, whose duty it is to clear the enemy out of the objective trenches. Also we have the A. M. R.'s, employed to protect the flanks of the wave. When the wave is halted they must be available for instant use against any nest of resistance and must therefore be in the first line. They are also used in the captured trench to withstand an enemy's counterattack, which may develop within five minutes after its capture.

The Second Line of the First Wave. We have here the rifle-grenadiers who help the hand-grenadiers break up the enemy's resistance and clear the trenches. This is done by a barrage of rifle grenades from the second line. Then, also, we have all the riflemen of the platoon, whose function it is to follow up the success of the specialists and drive the surviving hostile men out of the trenches with the bayonet.

Third Line of the First Wave. In this line we have the "cleaners" or "moppers-up." These are hand-grenadiers and their function is to clear the enemy out of the trenches, both laterally and in depth of the position. The assaulting column stays above ground and continues across the position to the third line of trenches, which is usually the limiting objective of the attack. The "cleaners-up" also picket all entrances and exits of dugouts to allow none of the enemy to come out after the waves have passed and fire into the backs of the assaulting troops.

These three lines compose the first wave, and we see that the specialists are placed in the lines in the order of their duties.

1. GENERAL USE OF FORTIFICATIONS.

The first use of fortifications, whether hasty or permanent, is to give shelter against hostile fire. The more deliberate use of fortifications is to increase the holding or fighting power of troops by the proper employment of the natural defensive features of the ground and by artificial devices.

2. SUCCESSIVE PHASES OF THE ORGANIZATION.

During a battle, as we understand it in Open Warfare, as soon as the fighting lines are halted for any reason, every man immediately begins to dig in for shelter against the enemy's fire. If the halting of these fighting lines is more or less permanent, these "skirmish holes" are connected, and we have the start of a rude trench. We must remember that in a battle, troops are disposed in depth in a series of lines. All these lines dig for protection in a

similar manner, giving the beginning of several lines of trenches. If the troops remain for any time in this position, it is necessary to have routes from the rear to the front to carry up ammunition and supplies to the different lines. These communication routes are also dug in, and we have the beginning of communicating trenches. Soon the men will begin to seek better protection against rain, cold and overhead fire and build themselves some kinds of shelter. In a similar manner command posts and supply depots are established.

In time there is a complete skeleton of a series of lines of trenches outlining a position. If the mission of the troops is to remain and hold the ground, the necessary plan of organization for the final position will have to be based upon this skeleton. The purpose of

FORMATION FOR COMBAT.

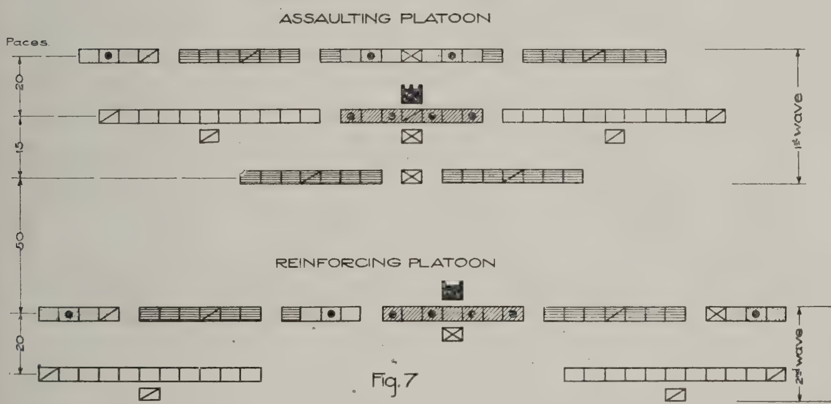


Fig. 7

this new organization, as we have noted, is to establish the position so that the ground can be held by fewer troops.

3. ACTIVE AND PASSIVE ELEMENTS OF A POSITION.

The first fire trench of a position is continuous, but it is not good practice to man the whole of this line, because this would take too many men and defeat the purpose of the fortifications. Secondly, a better defense can be established by garrisoning a series of strong points, or salients from which can be obtained flanking fire. In the first line these are called *support points.*

The trenches connecting these support points are retained as such, but are not usually manned. This curtain trench, so to speak, is retained for communicating purposes, and to deceive the enemy as to the real points of defense. A few watchers are left in it.

The first line, then, is a series of support points, well defended by men and special weapons, and at such distances apart as to support each other.

4. DIVISION OF POSITION.

The garrison of such a support point in the first line is a company, and the captain is responsible for the holding of this ground. (The platoon, we must remember, is a tactical unit.) In dividing the first line into these active elements, the size of each support point depends upon the importance of the ground or of the tactical situation.

Similar natural strong points are also located in the second line. They will be fewer and farther apart in this line than in the first line which is exposed to hostile attacks. These points in the 2d line are connected with the support points and together the group is called a *center of resistance.* The command of such a center of resistance, including one or two support points in the front line usually falls to a battalion commander with his unit. For example, the area of a center of resistance will include, say, two support points in the first line with a company in each, and the strong point in the second line with the other two companies of the battalion.

In the third line also, natural strong points are located and organized for defense. The command of this strong point, including, let us say, two centers of resistance, falls to a colonel with his regiment. Such an area is called a *sector,* or a *sub-sector.* Two such sub-sectors, each with a regiment as garrison, constitute a sector in command of a Brigadier-General.

5. DIFFERENT LINES OF A SECTOR.

We have now arrived automatically at the fact that each sector is composed of a series of lines in depth, usually three, each defended in strong points.

The first line is termed the *line of resistance,* as the first defense is made against the enemy's attacks in the support points of this line.

The second line is called the *support line.* In the strong points of the Centers of Resistance are the reserves and the headquarters of the battalion commanders.

The third line is called the *covering line of the artillery,* because it defends the batteries distributed behind it. It also contains the reserve troops of the Sector, a battalion usually holding each strong

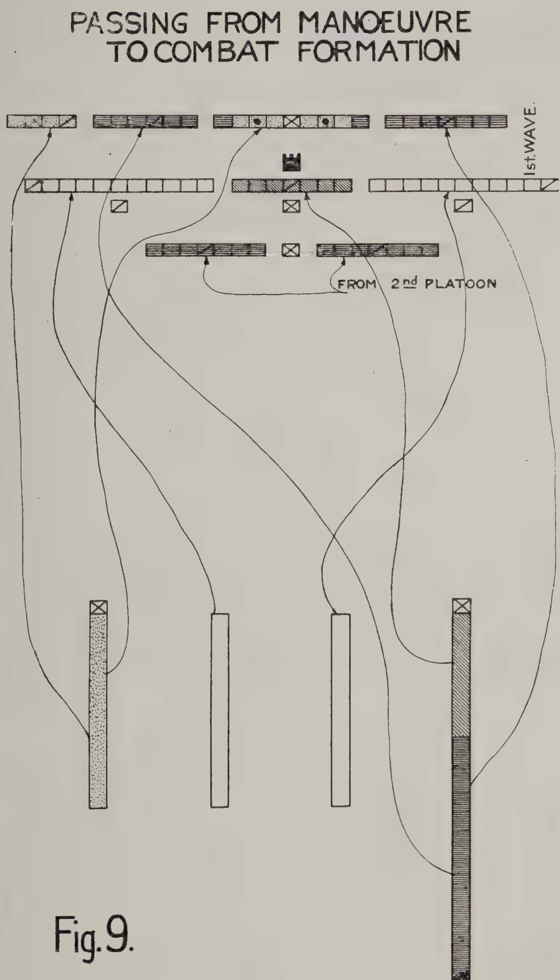
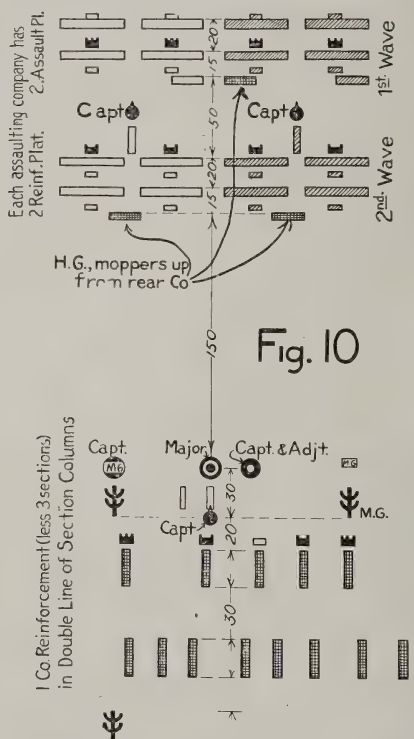

PASSING FROM MANOEUVRE
TO COMBAT FORMATION
1st. WAVE.
FROM 2nd PLATOON

Fig. 9.

point. Here is established the headquarters of the colonel and all the different depots of the Sector.

The above three lines constitute one position. There may be several positions in depth at distances of three miles or more apart. Usually there are two positions and sometimes three. It is said that the Germans have as many as six positions in depth in places. The first position, only, of course, is permanently occupied.



Battalion in Attacking Formation
Distances in Meters

II. PRINCIPLES OF THE ORGANIZATION.

1. The Advantages of the Continuous Trench Between Support Points.

The curtain trench between support points must not be eliminated for several reasons.

This continuous trench will deceive the enemy as to the location of the elements of support points. If the trench were absent the enemy could easily locate these, and subject them to concentrated

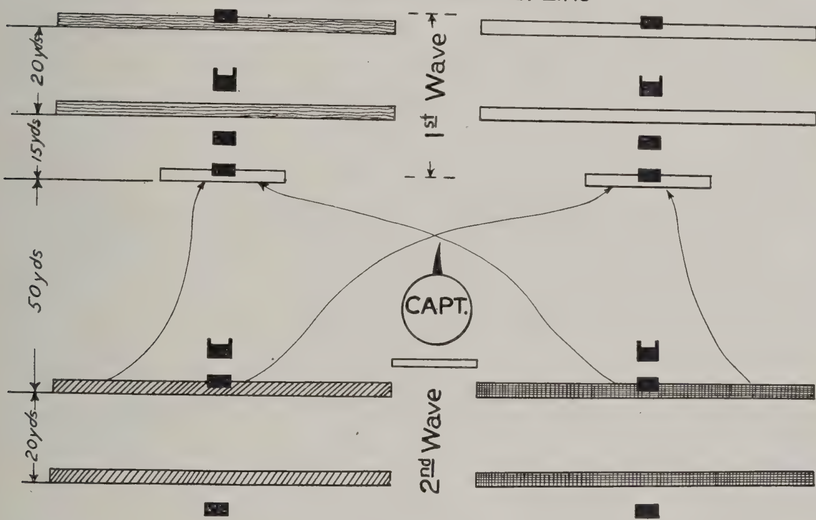
artillery fire. The position cannot be concealed from airplane observation but the essential elements such as emplacements, dugouts, etc., should be hidden.

The curtain trench serves for communicating purposes for lateral movements of troops and for liaison between neighboring units.

The absence of the curtain trench would leave breaches in the line where in a general attack units could concentrate and break through. In such a general attack the curtain trench is occupied

Attacking Company
Two Platoons in the First Line

Fig. 11.



and defended by the reserves. Barbed wire, of course, protects the entire front.

These trenches also serve if necessary as cover for reserves acting as reinforcements to the adjacent support points, because there is only sufficient shelter in a support point for its own permanent garrison.

Lastly, they serve as trenches of departure in the offensive.

2. Importance of Flanking Fire.

It is possible to have the support points at intervals because flanking fire from these will command all the ground in front of the first line (see Fig. 13). The importance of flanking fire cannot be overestimated.

Sometimes it is impossible to get flanking fire because of lack of salients. If this is true the trace of the first line trench must be rectified to give flanking fire along the line (see Fig. 16).

When neither of these two methods is possible small combat posts with machine guns are located in advance of the line to obtain flanking fire (see Fig. 17).

The machine gun is the best weapon for flanking fire. Several emplacements are constructed for each machine gun, but during the bombardment they are kept under cover in a dugout. When the attack develops the machine gun is quickly set up in the proper emplacement. If kept in a permanent emplacement the enemy will soon locate it and put it out of business.

If no emplacements are possible or they are destroyed, machine guns are operated on open ground or in shell holes.

3. *Field of Fire.*

With proper flanking fire a line can be defended with a shorter field of fire than otherwise. A hundred yards of field of fire is sufficient with such flanking fire and accessories as barbed wire, etc.

4. *Location of Trenches.*

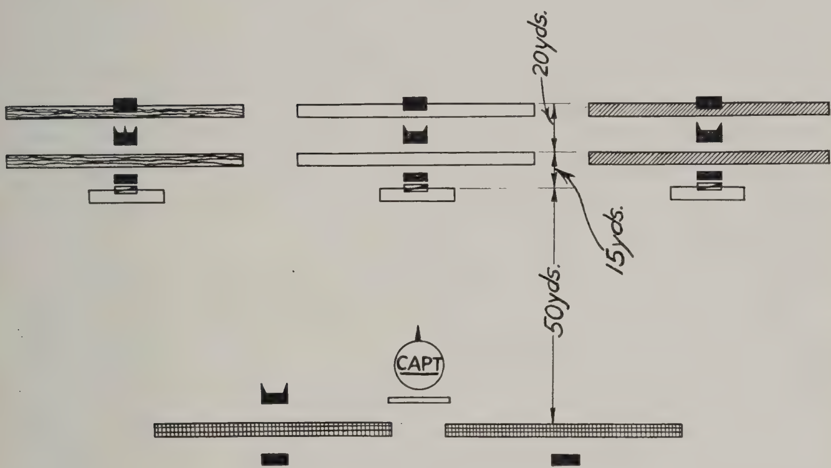
Lines of trenches which are the result of a battle are not always located in the most logical positions. They are the results of the exigencies of the battle. However, it is well to know the best locations for the trenches of a position under different circumstances in order to place them there when possible.

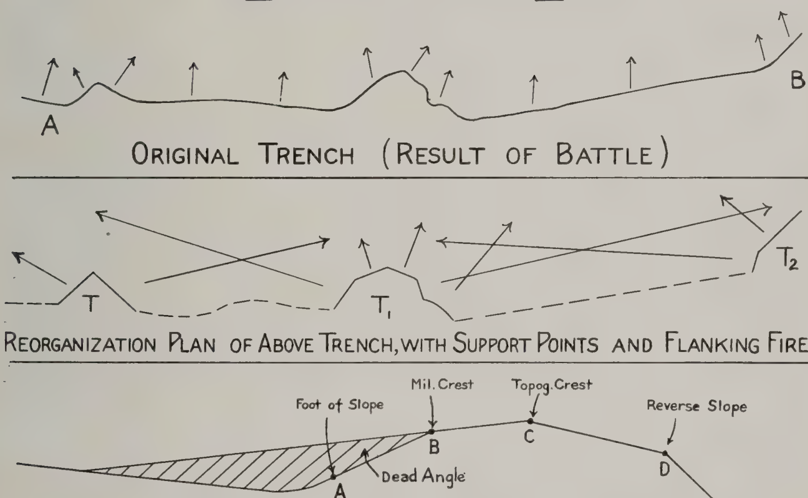
In flat country, of course, it makes no difference where the trenches are located. On the profile of a hill, however, the question is where to locate the first and where to locate the second line of a position. Let us consider (Fig. 13). Point A is out of the question, as you have no view of the enemy. At B you can observe the enemy's line and he can observe yours. However, the enemy can shell you at this point and observe the results. At C the same conditions obtain as B, except there is a dead angle directly in front. At D you cannot observe the enemy nor can the enemy observe your line. From these considerations we see that the proper location for the first line will be at B, as you must be able to observe the enemy and all the ground in front. Your second line should be located at D where the enemy cannot observe and bombard your position. At D, the line can be made as elaborate as you have time, men and

Attacking Company

Three Platoons in the First Line

Fig. 12





ORIGINAL TRENCH (RESULT OF BATTLE)

REORGANIZATION PLAN OF ABOVE TRENCH, WITH SUPPORT POINTS AND FLANKING FIRE

PROFILE OF HILL, TO SHOW LOCATION OF TRENCHES

Fig. 13

material, because you are more or less unmolested by the enemy's fire and observation.

The reverse slope is of the very greatest importance in organizing a position. Movements of troops and supplies can be easily accomplished here under cover. Deep dugouts can be constructed with the least work. But the greatest advantage lies during the bombardment. The enemy is not able to observe the accuracy of his fire on the reverse slope, so that the elements in this line are left more or less intact. For this reason the line on the reverse slope becomes the most important line of resistance against the enemy attacks. The Germans habitually organize their reverse slopes very strongly.

5. Division of the Position Into Defensive Compartments.

We have already spoken of the sector in depth by successive lines. In the same way it is necessary to organize the positions for lateral defense. A support point may be captured by the enemy and from this ground he can launch a flanking attack on the adjacent part of the position. It is necessary that there should be an established defense against such an attack, and for this purpose each sector is divided into compartments, so to speak, with all around defense.

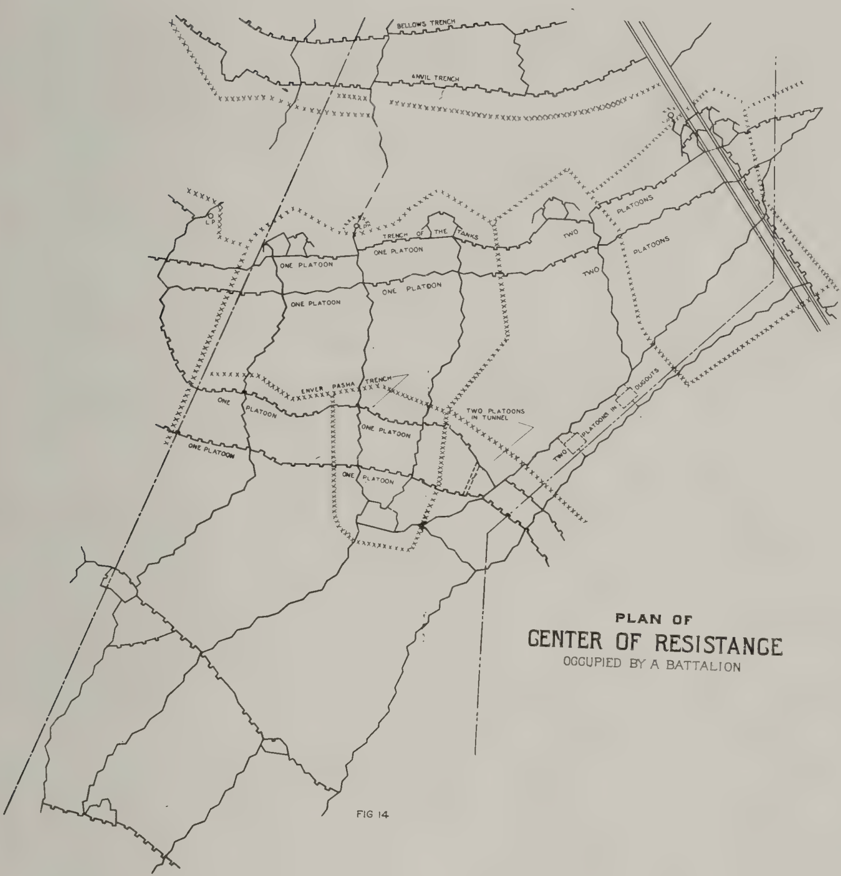
Communicating trenches on the flanks of these compartments are organized as firing lines with barbed-wire belts running parallel, and with machine gun disposed for flanking fire. We have, then, each sector cut up into compartments capable of independent resistance in all directions if the surrounding compartments are captured by the enemy. Such a compartment also has the advantage of serving as a base for a counter attack against an adjoining one that has fallen into the hands of the enemy.

In a sector the responsibility of such lateral defenses especially falls upon the Colonel.

6. Concealment.

All of these works are more or less without value if they can be seen by the enemy and subjected to heavy artillery fire. Everything that is possible must be done without the observation of the enemy.

It is important to hide your works by making them fit in with the color scheme and shape of the surrounding ground. False or dummy trenches, emplacements, shelters, etc., are constructed to



PLAN OF
CENTER OF RESISTANCE
OCCUPIED BY A BATTALION

FIG 14

cause the enemy to waste his ammunition on these. The art of camouflage is also extensively employed for this purpose against both ground and aerial observation.

III. ELEMENTS OF THE ORGANIZATION.

1. Plan of Organization.

We have seen that the first outline of the trenches left as a consequence of the battle must be modified in detail to obtain better protection and shelter. The complete plan of reestablishment is laid down by the Commander of the Sector and is called the Plan of Organization.

This plan is drawn up as soon as the position has a permanent garrison. The plan of organization must be faithfully followed out by all the successive garrisons of the sector. After its adoption, even the Commander of the Sector himself cannot modify the plan without consent of the General in charge.

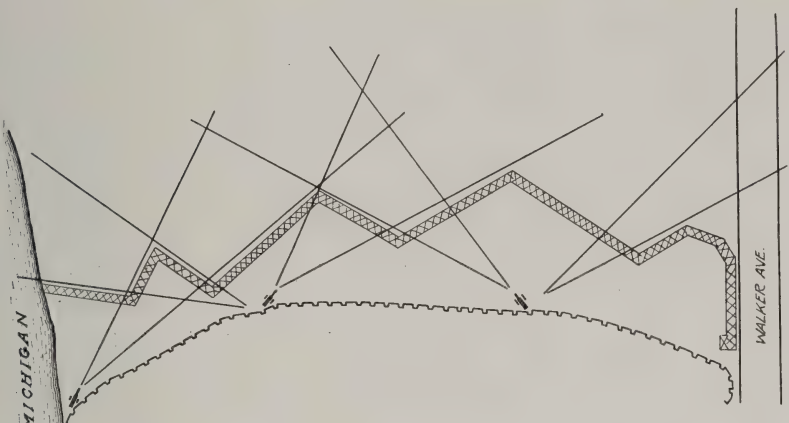
The real value of a position depends upon the amount of continuous work that has been done in carrying out the original plan.

2. Outline of the First Line.

As was seen before, the original trace of the first line was established as a consequence of the needs of the battle. In the organization plan, it is necessary to introduce several modifications in this trace.

The commander responsible for this change should place himself in the situation of the enemy and consider an attack upon his own lines. From these considerations he will introduce such modifications as will make this task as difficult as possible.

The responsibility of making this modification in the trace of the first line does not devolve upon the Captain in the first line. As a rule if it were left to him few changes would be made because of lack of initiative on his part, or because of fear that if the line were captured he would be blamed for having changed it. This task falls upon the Battalion Commander who is responsible for the Center of Resistance, with the consent of the Sector Commander. The reason for this is that the Sector Commander is the only one of these officers who knows the subsequent use of this particular sector, whether for defensive or offensive purposes. If for defensive purposes the line may be carried as close to the enemy's line as possible. If the sector is being organized for an offensive there must be enough distance between to keep his own line out of the zone of artillery dispersion, if the target is the enemy's line.



TYPE OF A GOOD ENTANGLEMENT BEFORE A FIRING LINE WITHOUT SALIENTS.

CENTER OF RESISTANCE BETWEEN WALKER AVE. & LAKE MICH.

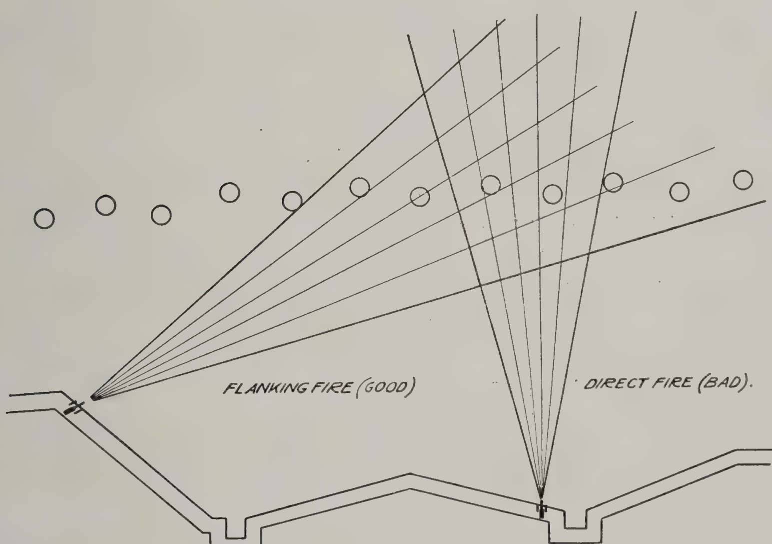


FIG. 15.

(a) Doubling or Cover Trench.

In general all fire trenches have a second trench behind, called the doubling or cover trench. The use of the doubling trench is not primarily for defensive purposes. It has special uses.

The majority of the troops in the first line are kept in the doubling trench in shelters located there. The first line is habitually manned by only a sufficient number of men to assure observation and security. The rest of the garrison remain in the shelters of the doubling trench to get as much rest as possible. It is very important that comfortable shelters be located in the doubling trench. If troops are exposed to the elements and bombardment their value decreases very rapidly. If the shelling becomes too severe the men in the first line retire to the shelters of the doubling trench until the attack develops.

Another use of the doubling trench in the defensive is to keep here a necessary number of troops for reinforcing the first line when necessary and for counter attack against the same if it is taken. This latter use establishes the distance between the two lines, which is from 30 to 40 yards apart, so that hand grenades can be thrown from the doubling trench into the first line.

Behind each support point there is usually a lateral communicating ditch called circulating ditch, which should not be confused with the doubling trench.

(b) Advance Posts.

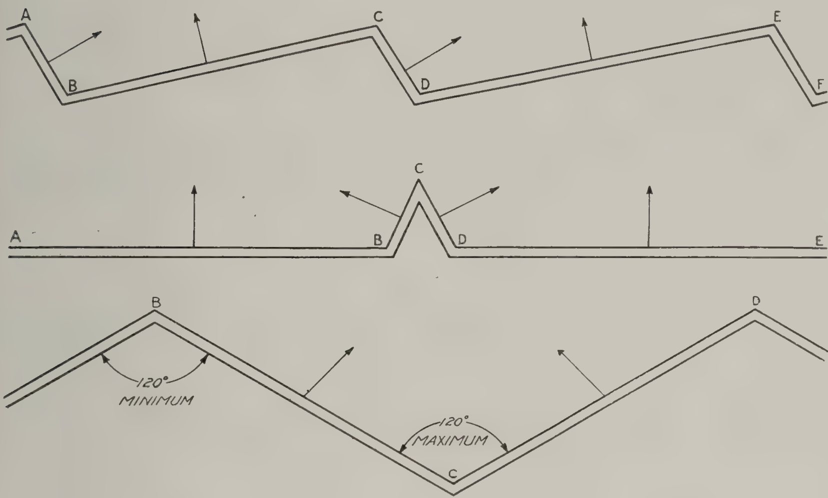
In front of the firing line certain advance posts are established. There are three kinds: listening, observation and combat posts.

The *listening post* is not under the control of the Commander of the Support Point, but is in the service of the Intelligence Officer. It is furnished with a microphone for the purpose of picking up enemy's telephone messages in the hostile line.

The *observation post* belongs to the *sector and is used* for purposes of observation and security.

The *combat post* is established to obtain flanking fire along the barbed wire entanglements (Fig. 17), or it is used as a bombing post when in close proximity of the enemy's trenches.

Sometimes a series of combat posts are connected and a new trench established in front of the firing line. This is called the observation line. It is best to avoid this practise, as there is always the question whether to hold or abandon this line when the enemy's attack develops. In either case these are grave disadvantages. If



TRACES OF TRENCHES USED TO OBTAIN FLANKING FIRE

TYPES OF COMMUNICATING TRENCHES

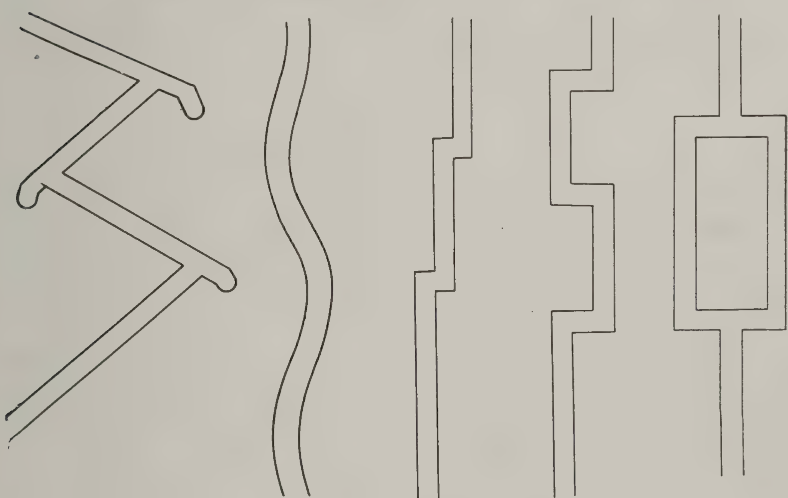


FIG. 16

it is held you have a weak line. If you abandon it the enemy can use it for shelter.

Advance posts give excellent service if not too numerous. If there are many of them they are a temptation for hostile raids.

(c) Dimensions of Trenches.

These can be found in all text books on the subject. The general idea is that they are to be narrow and deep to prevent observation and to present a small target for high angle fire.

(d) Loopholes.

Loopholes are used in the ordinary life of the trenches, in daylight, for observation and sniping purposes; but against the real attack of the enemy the firing is done over the parapet. If it is necessary to meet the enemy in hand-to-hand combat the men climb on top of the parapet.

(e) Traverses.

Traverses are used to localize the effect of shell or grenade explosions and to prevent enfilade fire.

They are sometimes used in long stretches of boyaux or communicating ditches as emplacements for A. M. R.'s to enfilade the same if the enemy penetrates.

(f) Transversal Lines.

Transversal lines are usually constructed between the first and the second lines and between the second and third lines. They are short stretches of trenches parallel to the front for special purposes; such as disposing of machine guns and trench mortars in depth, bombing posts for rifle and hand grenadiers, depots, and observation posts.

Command posts are usually located in such small transversal trenches, a little in rear of the lines they are in command of. For instance, the Captain in charge of a support point might be located in a transversal just in rear of the doubling trench.

3. Support Trenches.

The second or support trench is established at such a distance that the first line is covered by its fire if the latter is captured.

Also the second line should be placed so that it will be out of the zone of the dispersion if the first line is the artillery target, either of

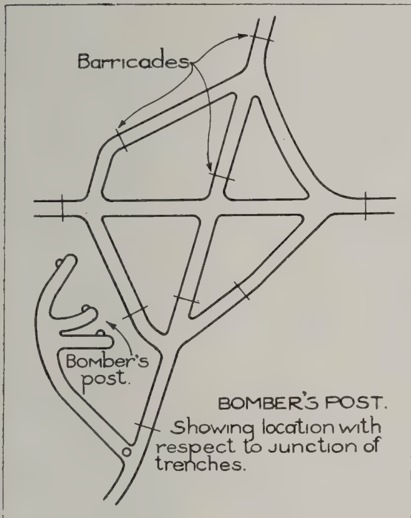


FIG. 19

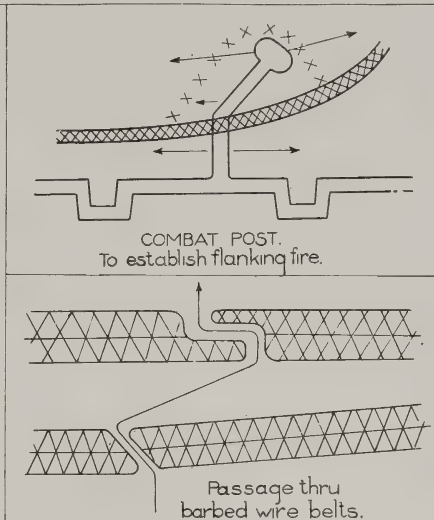


FIG. 17

COMMAND POST FOR CENTER OF RESISTANCE OCCUPIED BY BATTALION

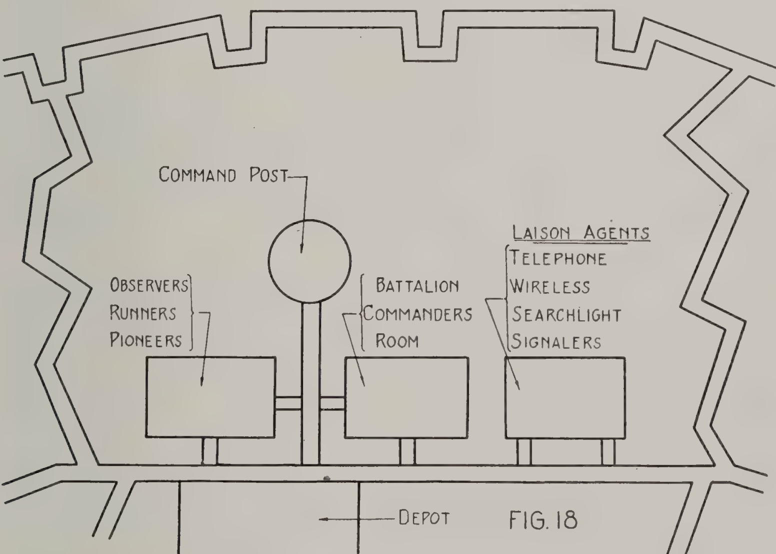


FIG. 18

your own or of hostile fire. This places the distance between the two lines at from 150 to 200 yards. At this distance rifle grenade fire can be used in conjunction with the artillery preparation.

The organization of the second line is the same as that of the first, in other words, the same principles and elements of defense are used making employment of barbed wire, flanking fire, doubling trench, etc.

The second line is the main line of resistance and must be made as near impregnable as possible. For this purpose, it must be thoroughly and completely organized.

In the support line are the reserves of the C. of R. and for their proper shelter they should have very deep dugouts, and all the requisites for the comfort and rest of the troops.

Redoubts.

Behind the support line is a redoubt containing the command post of the Battalion Commander. It is the last strong point of the Center of Resistance and is organized for an all-round defense.

The line of redoubts is the last line of serious resistance. If the enemy penetrates this line, you may say that a breach has been made in the position at this point.

Boyaux and Communicating Ditches.

As we have said before, trenches for communicating purposes must be dug both in depth and laterally. We shall call those from front to rear boyaux, and those laterally, communicating ditches.

The number of boyaux is not fixed as that of the different lines. There must be at least one between each support point and its Center of Resistance.

Usually boyaux are used for movements in both directions. Often certain boyaux are designated for entrance only and others for evacuation. The numbers of the latter are usually less than the former.

In an attack all boyaux are used for movement of troops from rear to front.

All movements to the rear while reinforcements are being brought up must be executed in the open ground, exceptions being in the case of wounded.

Boyaux are important for the movement of supplies and ammunition, but above all they are essential for reinforcements during battle. The greater part of the troops in a sector are held in

reserve in the second and third lines. This disposition is only possible if you have good boyaux to the front lines.

All boyaux and communicating ditches are narrow and deep. Boyaux are wider between the second and third line than they are between the first and second. Evacuation boyaux are usually wider than others. The trace of a boyaux must be such as to prevent enfilade fire (see Fig. 16).

At intervals of about 10 yards turnouts large enough for a stretcher are constructed in the side of the boyaux for passage of troops in different directions. Boyaux are named and signs are put up similar to those for streets in a city. The same name of a boyaux must be kept from the third lines to the first.

At branches the main boyaux is dug a little deeper to avoid mistakes of identification.

As stated before, certain boyaux are organized for defense.

It may be said here that supplies carried up at night are usually brought along on top of the ground close to the boyaux. This gives freer movement and the carriers are close to the cover of this trench if needed.

Accessory Defense.

Of all the accessory defenses such as barricades, abatis, troup-de-loup, etc., the most important by far is barbed wire, which is almost exclusively used as obstacles.

Barbed wire should be placed from 20 to 50 yards in front of the first line. At this distance, shelling of either the first line or the barbed wire belts will not do very much damage to the other; and the wire entanglements will be under fire of the first line, and close enough to prevent wire cutting at night.

The trace of the wire belt is not necessarily parallel to that of the firing line, but should be so placed as to obtain flanking fire along the wire belts (see Fig. 15). Good entanglements are constructed in double belts. The distance between the two belts being from 10 to 20 yards, the furthest belt, of course, being constructed first.

Breaches must be left through the wire entanglements for the passage of patrols, friendly raiding parties, etc.

All accessory defenses must be concealed so they cannot be destroyed by the enemy.

Command Post.

A Command Post in the full sense of the word contains the headquarters of the leader of a division of a Sector.

The Command Post must first of all be a good observation post, after that the other requisites are installed.

After the observation post has been constructed the following are built: a room for the headquarters staff to work and to sleep, a telephone central and a depot.

The preceding discussion is a development of a position from battle conditions. On the other hand, if you are unmolested by the enemy the order of organizing a position would be as follows:

(1) Construct the emplacement to obtain flanking fire.

(2) Construct barbed wire entanglements.

(3) Observatory and dugouts.

(4) Trenches.

Sector and Trench Duties.

When troops are in the trenches of a sector waiting and preparing their position against a hostile attack, we say that these troops are in a "Waiting Position." The work entailed in this preparation is called trench duties.

I. PLAN OF DEFENSE.

1. Definition.

The Plan of Defense contains all the different duties necessary to make a proper defense of the position. The execution of these duties is the execution of the Plan of Defense.

The Plan of Defense follows logically and depends directly upon the Plan of Organization.

2. Principles of the Plan of Defense.

(*a*) The most important principle of Organization of a position is the *disposition of troops in depth.* It is necessary to have plenty of support and reserve troops disposed, one behind the other. Only $1/6$ to $1/3$ of a garrison in the support point of the first line remain in the trenches for the purpose of observation and security. The rest remain in the rear as a reserve for reinforcements or counter-attacks.

(*b*) Each trench, each nest of resistance, each area of the ground, must have a responsible leader. *The garrison of any such area must never leave the ground allotted to its defense under any conditions*

of battle. The defense must be carried out by this garrison on the lines originally laid out. A leader is not allowed to fall back on troops in his rear or to take up a better position. The troops in depth are placed there for the purpose of reinforcements for the lines in front.

(*c*) *Each part of a position that is lost to the enemy must be immediately retaken by a counter-attack* carried out by troops held in reserve. The first line is retaken by reserve troops in the support line; and similarly, if the support line is lost, it must be retaken by reserve troops held in the third line. If all three lines are captured, an attempt must be made to retake the third line by the reserve troops of the sector.

3. *Form of Plan of Defense.*

In each division area of the position from front to rear there must be a Plan of Defense. This plan always contains the four following elements:

1. Directions of the probable attacks.
2. Defense of the first line, or line of resistance.
   The outline of the first line.
   Location and mission of the troops in the first line.
   Employment of machine guns.
3. Counter-attacks.
   Units which are used for the purpose.
   Directions or trenches to be used in the counter-attack.
   Depots of grenades and sand bags for the counter-attack.
4. Liaisons and Supply during the hostile attack.

II. DETAILS OF TRENCH DUTY.

1. *Guard Duties (Security).*

Security is obtained by the use of sentinels and patrols.

Sentinels must not be confused with Observers, Watchers or Snipers. Observers belong to the Information Service of the sector and are not on duty at night. Snipers only operate in the day time. The Watchers of the different lines give the alarm in case of an attack. Watchers, however, are on duty both day and night. Sentinels are posted in the first line or in advanced posts. Their work and number will depend upon the proximity of the enemy, the tactical situation, and above all upon the condition of the wire entanglements out in front.

At night one sentinel is posted, say, for example, every 10 yards in the fire trench of the first line. During the day only enough sentinels are posted so that all parts of "No man's land" can be observed. This will allow a maximum number of men to rest.

In the firing line the sentinels work in three reliefs. When not on guard duty they sleep. The remainder of the garrison in the doubling trench, however, are available for work, for patrols, and to furnish supply parties. Sentinels should have their rifles resting on the parapet close at hand ready to fire at a moment's notice.

By day the sentinels use a periscope or observe through a loophole. This practice is, however, strictly prohibited at night, when the sentinel must observe over the parapet. As little challenging as possible is done and then only in a very low tone.

Reconnoitering Patrols are the best means for security against attack. Every night the commanders of the support points, or the centers of resistance, send out patrols in front of the firing line. The strength of a patrol must be sufficient to allow them to carry a wounded man, *i. e.,* the number should be 5, 6 or more. The success of a patrol depends entirely upon the leader. He must be clever, daring, and observant; and the rest of the patrol is simply his bodyguard. He, himself, must observe the objective of the patrol's mission.

Patrols should never be sent out without definite orders as to their mission. Such may be, for example: A reconnaissance of the enemy's lines, to discover if the enemy has cut passages in his wire belt preparatory to an attack, to examine their own wire entanglements, etc.

The route of the patrol must be exactly determined, also the hour of departure and return designated. Word is passed along the line of sentinels that a patrol is out in front, with the necessary information. The preparation for a night patrol must be made during daylight.

Officer of the Watch.

In the firing line the Company Commander arranges a roster of his officers for duty as *officer of the watch.* Also in each platoon the platoon commander will detail a N. C. O. of the watch. The officer of the watch is responsible for the duties of observation and security; and is especially responsible for giving the alarm in case of an attack, and consequently for the calling of the artillery barrage by use of rockets, signals, etc.

Standing to Arms.

It is of the greatest importance that the troops in the first line are thoroughly trained in taking their positions when the alarm is given, as quickly as possible, without confusion. The alarm is often given for practice in order to ascertain the amount of time it will take the men to reach their places in the firing line.

The command, "Stand To," is usually given one hour before daylight and one hour before dark. At this time the company commanders arrange for inspection of arms, ammunition and equipment by the platoon commanders.

2. *Observers' Duties.*

Every effort should be made to obtain information of the enemy, his trenches and his wire entanglements. Any alteration in the enemy's lines must immediately be reported. The importance of forwarding such information must be impressed upon all ranks.

All men of the company are used as sentinels in the first line, or as watchers in other lines, but not all are observers. Men who are to act as observers receive special training. A man to become an observer must have a special capacity for this task, as eyesight, hearing, patience, etc.

Each platoon should have at least six such observers, enough for proper relefs.

The observers are placed:

1. In each company the observers are distributed in a number of observation posts properly camouflaged so as not to be discovered by the enemy. These posts may be in advance of the firing line, in the firing line, or at any point within the position that has a wide view in the front. The observers employ periscopes or field glasses. Everything of note that is observed is recorded and from these data the captain makes out his daily observation report.

2. Also in the sector there are two or three observatories from which the information is turned in directly to the colonel. These posts must be properly concealed and protected. In each one of these we find the following:

(*a*) Regulations posted that give the personnel, tour of duty, sector of observation, direction to special points of interest and certain precautionary measures.

(*b*) Specially prepared blank forms upon which to record information gained by observation.

(*c*) Field glasses, maps and sketches, and panoramic views of the ground in front, both visible and invisible from the observation post.

(*d*) A telephone connecting the post with the nearest commanding post (center of resistance or sector).

The observers in these posts are directly under command of the Intelligence Officers of the regiment and are of a special personnel. They must be thoroughly familiar with the regulations of the posts, maps, panorama, etc.

The Intelligence Officer gathers and co-ordinates all information gathered in the sector. Every morning he turns in a consolidated report made up from the information in the captains' daily reports and from the records of the sector observatories. (In order to avoid confusion of the different daily reports these information records are kept on different colored blanks, red and blue, alternating each day.)

The report of the Intelligence Officer is signed by the colonel and sent on to the brigade headquarters. From the data of his complete report the Intelligence Officer very often must verify certain information by the use of patrols. For this purpose he makes a request upon the colonel for special patrols.

Information is gathered from both airplanes and ground observatories. From ground observatories it is attempted to obtain the following data:

1. To ascertain the intentions of the enemy.
2. To keep maps up to date by showing daily alterations in the enemy's lines.
3. To properly prosecute attrition of the enemy's works.

3. *Attrition.*

By the word attrition in fighting is meant the gradual destruction of the enemy's morale and strength; and demolition, little by little, of the enemy's position. Trench warfare is not a rest or simply a time for guard duty. It is a phase of the battle in which you must do as much damage to the enemy as possible.

This work will also keep up the offensive spirit. For this purpose of attrition different means are used:

(a) Sniping.

Each company in the first line uses its best shots as snipers. A sniper must be a good observer and he must depend upon his

keen eye for evidences of the enemy, such as smoke of a cigarette, the glint of a bayonet, giving proof of the presence of an enemy. Especially during hostile shelling will a too curious enemy come to his loopholes to observe the effect of the same. This is the sniper's chance.

In each center of resistance the snipers are placed under the command of a sniping officer. He makes the rounds of the snipers' posts once or twice a day, and submits a daily report containing known casualties of the enemy, location of the number of snipers' posts, telescope rifles, fixed rifles, and rifle batteries.

(b) Infantry Weapons.

Besides sniping, all the other infantry weapons are used to assist attrition of the enemy. Hand and rifle grenades are thrown on special points of the hostile line. A battery of hand or rifle grenadiers properly disposed can very often carry out a concentrated surprise fire on an enemy's salient or advanced post. Automatic and machine guns are also used for this purpose and especially at night. They are trained on supply routes, road junctions, etc., and by use of sudden bursts of fire at irregular intervals they will compel the enemy's supply parties to continue their transportation in the boyaux instead of on the open ground.

The use of indirect machine gun fire is very depressing to the enemy. Such judicious employment of machine guns is sometimes more effective than severe artillery shelling.

The 37 mm. gun, which is also an infantry weapon, is used principally against hostile machine gun emplacements. The location of this gun must be constantly changed as it draws hostile artillery fire.

(c) Use of Artillery Weapons.

Besides furnishing barrage fire against hostile attacks the artillery can be called upon for surprise fire on working parties, harassing fire during the night against supply parties and their routes, and also for reply fire against hostile shellng.

Trench mortars and other engines keep the enemy as uncomfortable as possible at all times.

(d) Fighting Patrols and Raids.

Fighting patrols and raids are used with the express purpose of causing loss and damage to the enemy. This is accomplished by

engaging the enemy's patrol and working parties or by raiding his saps, listening posts or trenches. Such operations must not, however, degenerate into frivolous local fighting, causing loss of men and waste of artillery ammunition.

4. Work.

Daily trench work consists of maintenance and new construction.

(a) Maintenance.

The daily work of maintaining the elements of the position is considerable, and its importance often escapes those responsible for the same. They are:

Repair of parapets, boyaux, and shelters damaged by bombardment, water or frost.

Replacing or completing accessory defenses, revetments, ammunition recesses, emplacement of machine guns, observation posts, depots, etc.

The garrison of each area is responsible for their own maintenance work and drainage of trenches, which is done usually during daylight hours. Sometimes during severe bombardments this repair and maintenance work becomes too great for the garrison and workmen have to be called in to help.

(b) New Construction.

New elements of the position are constructed in carrying out the Plan of Organization. This is usually done at night. This work is carried out by troops in the doubling trench, the support line, or detachments of workmen from the reserve of the sector. There may also be special parties from the headquarters detachment of pioneers or from the engineer.

For all these special works the personnel for whom they are built must be present during the construction to furnish necessary help and information, and for inspection. A machine gun crew helps in building its emplacement, the Intelligence Officer directs the construction of his observatories. The medical officer is present during the work on the medical aid station, the telephone officer superintends the establishment of his telephone exchange, etc.

The battalion commander is responsible for all the work done in his center of resistance, and in conjunction with the sector leader, draws up a time table of the work.

All this work must be continued by each succeeding relief.

When a new unit takes its turn in the trenches the orders and plans of new works are turned over to its commander.

5. Arms, Equipment and Ammunition.

Full equipment will always be worn in the firing trench except the haversack, water bottle, and entrenching tool. In the support and reserve trenches the equipment to be worn is subject to the will of the sector commander. Every man will always carry a gas mask in any part of the position and even as far to the rear as 10 miles.

The men in the firing line and in the doubling trenches will at all times be in possession of their rifles and bayonets. The rifles of men in the support and reserve trenches may be kept in protected racks in the same shelter as the men.

All rifles must be kept scrupulously clean at all times.

Ammunition is protected from bad weather by being placed in boxes located in the sides of the trenches.

Ten to twenty hand grenades are placed in a sand bag. These are usually kept at the depot and carried in these quantities for the supply of the fire trench in combat. One or two of such sand bags are kept at a bombing post.

Special care must be taken to keep rockets in good condition. Supplies are kept in the fire line (platoon leaders' posts, observations), and at points in the rear (in the observatories, different Command Posts or in the observation posts of the information service).

6. Depots and Supplies.

(a) Depots.

There should be one general depot in each area, located near the command post of the chief of the area. However, in order to facilitate work in the first line the platoon leaders may establish, near their posts, a small depot of tools and material being used for the time being. The importance of the depot depends upon the area it is to supply. For example, the depot of the garrison of a support point in the first line would contain:

20,000 cartridges.
1,000 hand grenades.
400 rifle grenades.
100 each—signal and illuminating rockets.
60 to 70 gas masks.
100 shovels.
100 picks.
Sand bags, planks, barbed wire, etc.

The depot at the center of resistance contains the same articles but in greater number; also telephone wire, blankets and three days' rations of food.

The main depot of the position, however, is the one near the command post of the leader of the sector. It is divided into three parts:

1. Ammunition and rocket signals (Ordnance Service).
2. Material of every sort (Engineer Service).
3. Food and clothing (Quartermaster Service).

The different services in the rear of the position maintain the supplies of the sector depot. The amount of ammunition to be carried is fixed by orders from the general and this amount must be strictly maintained.

(b) Requests or Requisitions for Supplies.

Each morning the chiefs of areas send in a requisition for material required for the next night's work. All these requests in a sector are grouped, by a staff officer, under the heads of the three different services. Along with each request must go information showing necessity for same. Emergency requests are made by telephone. The officer making a request for material must be on hand to receive and check the same upon delivery.

(c) Supply Parties.

The supply of the depot is usually made with special detachments taken from the support or reserve companies. If it is necessary to take men from the front trenches for this purpose, no more than 10 per cent can be taken away from these trenches at one time. Complete units will be used as Supply Parties, with this leader, if possible. Upon each battalion in a C. of R. and upon each regimental reserve falls part of the responsibility of distributing supplies in the rear of the sector. The unloading or rendezvous points are disposed along what is called the supply line, usually on a road, path, ravine, behind a hill, etc. Supply parties sent out at night to these points make as little noise as possible. They return along a well-picketed path, usually running along one of the central boyaux. Transportation is thus carried in the open ground as far as possible, usually to the support line.

When proper protection is possible pack trains are used to carry supplies right through the distributing point and up to the depots of the sector.

(d) *Cooking.*

The battalion kitchens are located behind the sector in a protected emplacement. Steps must be taken to insure that as little smoke as possible is seen from it. At night each platoon sends a ration party to the kitchen.

When the regiment has rolling kitchens, these are brought up part of the way towards the sector where they meet the ration party. Arrangements should be made to always have, if possible, some hot soup or drink available for the men between midnight and 4 a. m.

(e) *Activities of the Troops.*

Sector duties include a considerable amount of work, which is not only useful for a tactical point of view, but also indispensable for the moral and physical welfare of the troops. Men without occupation in the trenches stagnate, grow slack, and think only of the time when their relief will arrive. Such troops lose their aggressiveness, so that when the time for the offensive arrives they have no confidence and cannot deliver the proper blow.

Good practice to obtain fruitful results is the employment of time as follows: In each company the captain prepares a daily schedule of duties in which he allots the different services of the strong point; hours of "standing to" and inspection, of sending ration and supply parties, time of rest, of cleaning arms, equipment and clothing, time of trench work, etc. This schedule is communicated daily to each platoon at a regular hour.

(f) *Discipline in the Trenches.*

Life in the trenches is not especially dangerous when all precautions are observed. In the presence of an alert enemy, every faulty move or disposition receives its punishment, as improper concealment of a movement, poorly hidden trench works, useless noise in the firing line. Silence is one of the essential rules of the trench. Silence in a sector enables the chief to rapidly transmit his orders, and the men to accomplish the same without delay.

7. *Daily Reports.*

In each sector, from the captain up, the different commanders must furnish a daily report. These are co-ordinated in the headquarters of the sector commander, and afterwards sent to the division headquarters.

(a) Telephone Reports.

Night report, 5 a. m. to 7 a. m.
Day report, 3 p. m. to 5 p. m.

These reports contain the main events of the time covered. Similar messages are sent at any time important events occur, such as heavy shelling, important information of the enemy, activities in the air, etc.

(b) Written Reports.

The daily morning written reports contain the following paragraphs:

1. General aspect of the sector.
2. Important events of the day.

(The events must be reported in detail, for example: A report of shelling must contain the details as to the area bombarded, the caliber of the gun used, number of shells, and the time and direction of same, etc.)

3. Casualties (wounded, killed and missing).
4. Consumption of ammunition.
5. Requests for miscellaneous equipment and material.

This report is signed by the chiefs of the area responsible for the information in the report. Along with this official report is added a second written report with the following paragraphs:

1. Request for materials for the night.
2. Observation and information reports. (To the Intelligence Officer.)
3. Report of all the work done in the sector, including time schedule of the center of resistance.

III. Use of Infantry and Artillery Weapons, and Liaison.

1. Machine Guns.

The tactical use and location of machine guns in the sector depends upon the following two principles.

(*a*) Machine gun emplacements must be thoroughly concealed, and during the bombardment, the M. G. itself is kept under cover, in a dug-out. Previous to an attack of the enemy, his artillery searches the position for the destruction of the machine guns and their emplacements, because they are the most powerful weapon of the defense.

If invisible casemates can be constructed this practice is good. The best method is, however, to prepare several emplacements, properly camouflaged, with a deep dug-out near at hand for the protection of the M. G. and its crew. This shelter must be located at such a point that the M. G. can be quickly brought out to any one of its emplacements when the attack develops. These emplacements usually are simple pits located in front of the trench and connected with the dug-out by a gallery. When emplacements are destroyed by hostile artillery fire, or when they are not possible, machine guns are pushed into shell holes or operated on the open ground. Shell holes out in front give the best service as emplacements for a daring M. G. crew. The French success at Verdun depended to a great extent upon the judicious use of shell holes for M. G. flanking fire.

(*b*) Machine guns are not only located in the first line, but are disposed throughout the interior of the position. The hostile artillery may entirely destroy the first line of defenses, but the proper disposition of machine guns for flanking fire in the interior lines will prevent the enemy's progress after penetrating the first line. Machine guns are so located in the position as to cover all the space between the different lines with flanking fire. Usually three pickets define the sector to be covered by any one M. G., one at the M. G. and two limiting its sector to fire.

In a sector, one-third of the machine guns are located in, or near the first line. One-third is disposed of in the support line, or in the redoubt. The last one-third is assigned to the third line. In each line machine guns are under the command of the chief of the area.

As a general rule, in the first line, automatic machine rifles, because of their mobility, are used instead of machine guns. Few, if any, emplacements are prepared in the first line. Grooves in the parapet are used for the A. M. R.'s.

Standing orders are, that M. G. crews will never surrender, but fight to the last man. Often the tenacity of a M. G. crew has permitted the retaking of an area otherwise lost.

2. *Trench Mortars.*

In each sector there are located a certain number of trench mortars. These are efficient weapons, but must be used with care, because they will nearly always draw concentrated artillery fire.

They are used for the destruction of special points in the enemy's lines that the artillery cannot reach.

They are employed in the preparation for an offensive against the enemy's first line, either for an attack or for a raid. They are used for reply fire against enemy's trench mortars.

They participate in establishing barrages.

The efficiency of trench mortars cannot be over-estimated, but at the same time great precaution must be taken in their use and concealment. The personnel required to serve the light trench mortars are taken from the garrison of the sector and belong to a special headquarters unit, a platoon of bombardiers.

The large trench mortars are commanded by an artillery officer who keeps himself constantly in liaison with the commander of the center of resistance. He consults the latter on the location of his mortars, and especially upon their use. He also reports to the commander of the center of resistance all orders he receives from his artillery chief. This artillery officer always works in co-operation with the chief of his area, who in turn gives him all necessary information and help. Especially does the mortar commander require help for the supply of ammunition.

ARTILLERY SUPPORT IN A SECTOR.

1. Composition of the Artillery Support.

The light artillery of this sector is not directly under the command of the Division Commander. The Commanding Officer of the light artillery, usually a Colonel, in co-operation with the chief of the sector, divides it into different parts, assigning one to each of the centers of resistance. This artillery is called support artillery. As we shall see later, this practice is usually the same in the offensive.

The amount of artillery allotted as support depends upon the tactical situation, in other words, the activity of the enemy.

In the Verdun and Champagne offensives the disposition of light artillery was the same in principle as that for the defensive, that is to say, one troop of artillery consisting of three batteries were assigned to each infantry battalion.

The general use of this artillery is:

(a) To protect the infantry with barrage fire.

(b) Prosecution of destruction of the enemy's personnel and works.

2. *Tactical Liaison between Infantry and Artillery.*

To carry out its functions, the artillery support must be in perfect liaison with the infantry, and only when this is done is co-operation of the two arms possible. This liaison is obtained by the following five means:

(a) Organization of the Leadership.

For the full co-operation of the infantry and artillery, the latter is not kept entirely independent, but is divided and assigned to infantry units. Each chief of sector and each chief of center of resistance knows what artillery must support him if he needs it. The Commander of the Artillery support is not exactly under the command of the infantry chief of area, but he is at the latter's disposal for certain calls for support fire. The proper co-operation of these two officers will give efficient results.

(b) Relation between Artillery and Infantry Commanders.

The best of relations must be established between the artillery and infantry commanders. Usually, it is not possible to locate the command posts of the two officers close together. Each has his area or unit to command and for that purpose must be located for the proper control of the same. The support artillery commander, however, should make frequent visits to the infantry leader and his area. He should also send his subordinate artillery officers into the infantry area to become acquainted with the first line, the conditions in ''No man's land,'' enemy's lines, and to gather all the information possible from the infantry officers in the trenches. Everything should be done to foster good relations between the infantry and their support artillery and this is best done by frequent visits of the artillery officers to the infantry trenches to gather information for artillery data.

(c) Communication of Orders.

It is necessary that the orders received by the infantry commander be communicated in whole or in part to the artillery commander, and vice versa. For instance, if the chief of area receives orders to send out a fighting patrol or a raid, this information is sent to the artillery commander, who, in turn, sends back his plan of action. Similarly, when the artillery commander expects to carry out special fires not called for by the infantry, such as,

destructive shelling, harassing fires, etc., he should first notify his infantry chief of area.

Similarly, any useful information picked up, either by the infantry or artillery, must be communicated to the other. The daily report of the chief of sector and the observation report of the Intelligence Officer are sent direct to the commander of the artillery support. Valuable information obtained at the artillery observation posts is sent to the infantry.

(d) Means of Communication.

The principal of the organization of the different means of communication is such as to assure the best liaison between the two arms. Telephone lines, searchlight signals, runners, etc., are established directly between a unit of infantry and his artillery support. This is to avoid loss of time and useless interruptiou between leaders.

(e) Detachments for Liaison and Observation.

For more efficient liaison between the artillery and the infantry, usually a certain number of artillerymen are sent from the group of the artillery support to the infantry area. Usually a special detachment of artillerymen is sent. This detachment is made up of one officer, chief of the detachment who is sent to the chief of sector, one N. C. O. to each chief of a center of resistance, the rest as telephone operators and artillery orderlies. This disposition of artillerymen in the infantry area is obligatory for an attack, but it is so practical that it is now employed in the sector organization.

The task of the artillery officer or N. C. O's is:

(1) To control all means of communication with the batteries of the artillery support.

(2) To transmit to the artillery the different calls for fire, and in technical terms to give the proper data for the laying of the pieces on the target, and the kind of fire required.

USE OF ARTILLERY SUPPORT.

Different kinds of fire are executed by the artillery support. The most important is the barrage.

Barrage.

Purpose. The purpose of a barrage is to stop a hostile attack before it can get started, or to hinder enemies' reinforcements or reserve troops from coming forward.

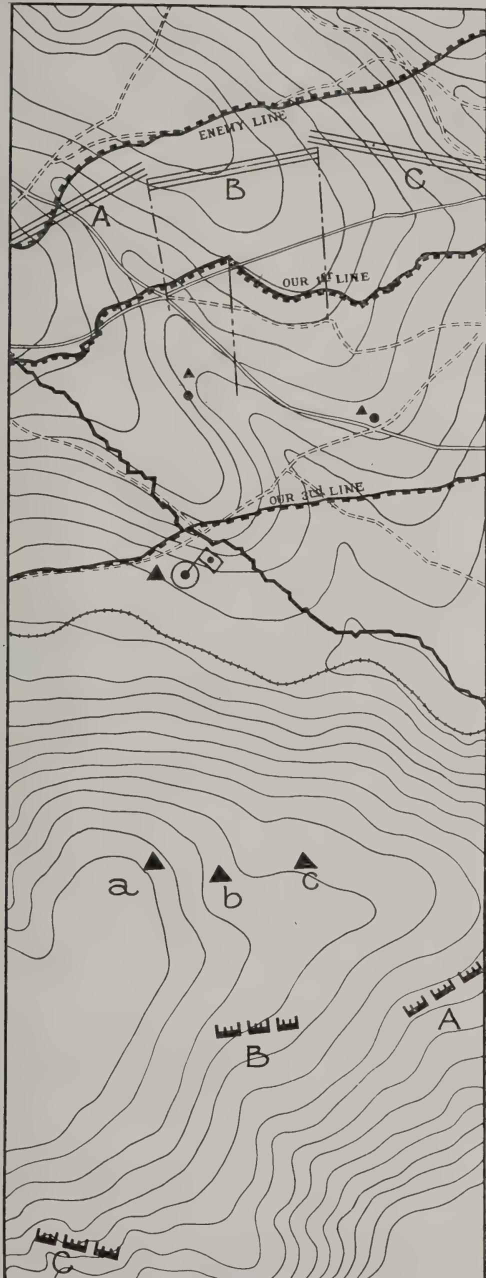


FIG. 20
EXAMPLE OF BARRAGE FRONTS
GROUP "A" ART. IS RESPONSIBLE FOR
"A" FRONT, ETC.

Form. The barrage is a curtain of fire let down in "No Man's Land," as close in front of your first line as possible, without loss to your own garrison. This will be about 150 or 200 yards to the front, between the two lines of trenches.

Front of the Barrage. The barrage has real value only if it is impassable. This will be so if the density of the fire is so great that the danger zones of the explosions of the individual shells overlap each other. The allotting of one group of artillery, 12 guns, for an infantry battalion is quite sufficient for this purpose if the front of the battalion does not exceed the average length of from 400 to 600 yards. (See Fig. 25, page 757.)

Duration. The barrage is a burst of fire which lasts from six to ten minutes. At the beginning the fire is very rapid and towards the end becomes slower. For instance, for the first six minutes the fire may be six rounds per gun and in the last four minutes, say, four rounds per gun. Successive barrages can be carried out, depending upon the needs of the infantry.

Calling for the Barrage. Barrage fire, for the best results, must open up at the moment the hostile attack begins. To accomplish this the call for the barrage must be made by an observer in the first line. For this reason every officer in the first line has the authority to call for the barrage. The barrage is the only fire that can be called for automatically by signal.

The kind and color of the rocket signifies the type of barrage required and the front it is to cover. In order to avoid mistakes this rocket signal is repeated from some point farther to the rear, usually at the observatories of the command post of the center of resistance, or the sector. Rocket signals are repeated until the barrage fire opens.

Confirmation of the barrage is given by telephone, if possible. However, at the first signal rocket the artillery is required to open up the barrage fire as quickly as possible without waiting for confirmation. Barrage fire is at the disposal of the infantry and cannot be refused by the commander of the artillery, whether it is justified or not.

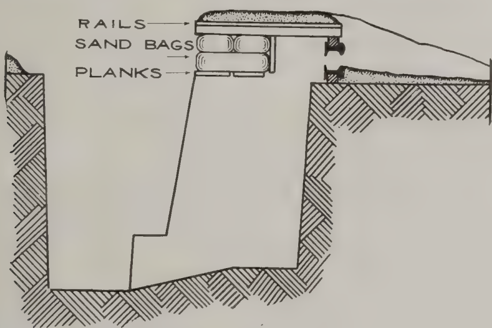
Other Kinds of Artillery Fires.

The commanders of the center of resistance or of the sector may call on the artillery support for other fires besides the barrage, such as:

Reprisal fire on the enemies' lines.
Reply fire to hostile shelling.
Surprise fire on supply attachments or working parties.
Destruction fire on special points.

All these fires are called for by telephone, but do not follow automatically like the barrage fire. The artillery commander, in such case, can use a certain amount of discretion whether these fires should be carried out or not.

Last of all, there is the counter preparation fire, which is a strong shelling of the enemies' position. It is carried out as a reply to a methodical bombardment of the enemy preliminary to his offensive.



OBSERVATION POST
FIG. 22

It is the best means to prevent a hostile attack. If this fire is well executed the enemies' assault is "Killed in the Egg," as the French expression has it.

1. Liaison in the Sector.

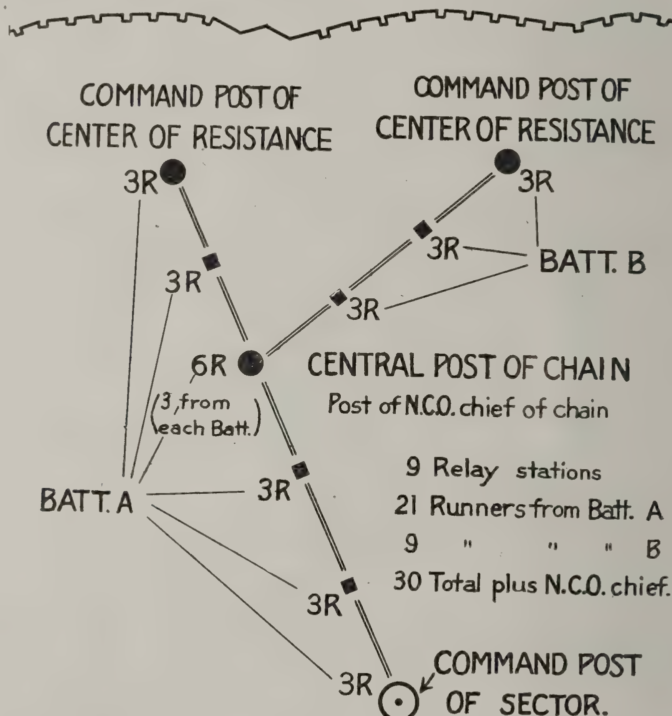
(a) Telephone.

There are two different systems of telephones. First, there is the system connecting the infantry command posts, support points, centers of resistance, sector, and division headquarters, with the command posts of the artillery protecting the different infantry areas. These are direct lines between the command posts and the groups of support artillery. Also, this system connects the command post with observatories, depots, medical aid stations, kitchens, etc.

Secondly, there is the system connecting the chief of artillery with his subordinate commanders, the artillery observation posts,

and the artillery dumps. In this same system the artillery command posts are again connected with the infantry units which they are to support. Special lines are run by the artillery to the officer and N. C. O. of the artillery attachment of liaison in the infantry areas.

Consequently, the liaison between the artillery and the infantry is doubly provided for in these two systems.

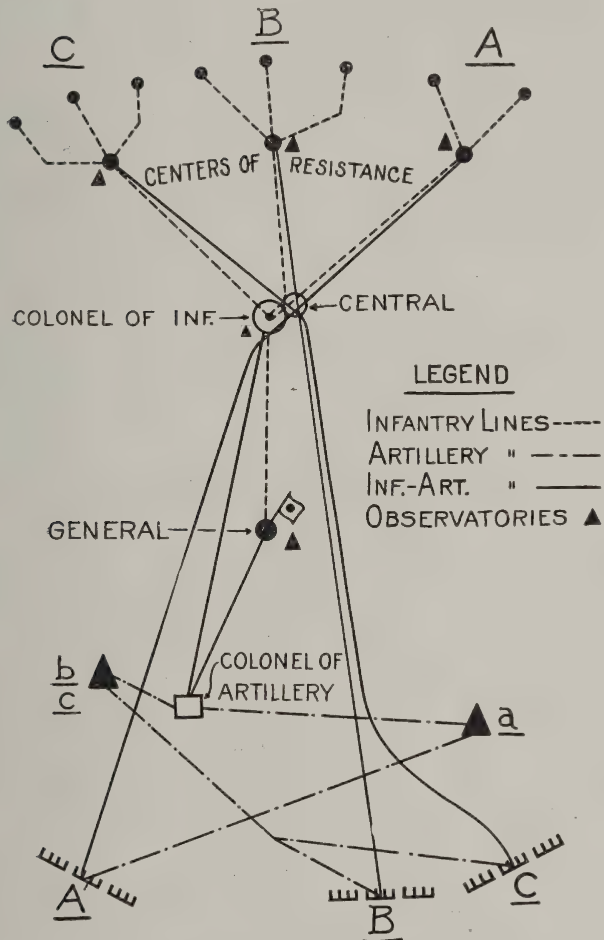


EXAMPLE OF A CHAIN OF RUNNERS

Fig. 23

The lines of connection between the infantry and the artillery must be separate from those within the infantry area and those between the artillery commander and his subordinate units.

Confidential information should never be telephoned except in cipher. Conventional designations are employed to call the different posts. Strict regulations are maintained as to who should use the telephone and for what purposes.



TELEPHONE LIAISON

Fig. 24

The weak point of a telephone system is that it is often broken by bombardment or earth-slides. This can be partially remedied by constructing as few direct lines as possible, by burying the wires in the bottom of the boyaux, and by executing repairs as quickly as possible.

(b) Wireless and Ground Telegraphy.

The battalions in the first line have ground telegraph apparatus to make connection with the regimental headquarters, and this, in turn, can communicate with the general headquarters by wireless. This means of communication is only employed when the telephone cannot be used.

(c) Signalling.

It is difficult to establish signal communication within the sector without being seen by the enemy. However, at night, with flash-lights, it is possible, especially in hilly country, to communicate from front to rear within the position. The receiving post should be able to certify received messages. When practicable, communications should be established between the command posts of the center of resistance and the sector command posts, and, from the latter post to the artillery. This method of liaison is organized as a duplicating means, or as a temporary substitute for the telephone.

(d) Rockets.

Signal rockets are used to communicate with the rear. Different forms and colors of rockets are used to signify different things. As we have seen, the most important use of the rocket is to signal for barrage fire. It is often necessary to relay a rocket signal from a second position in the rear to make absolutely sure that it reaches the artillery support.

Signal rockets are also used to communicate with aeroplanes, but this means is usually only employed during an attack.

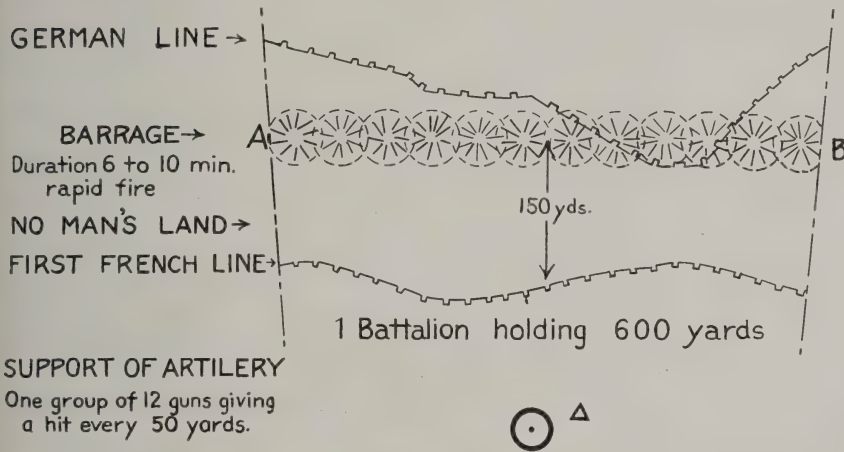
(e) Runners.

The liaison established with runners is best of all, from the point of view that it seldom fails. During heavy shelling it is the only sure means of communication.

The ordinary messengers or orderlies are not used as runners. A chain of trained runners is used, located in little post shelters, or shell holes. Each post contains three runners, their distance being from 150 to 300 yards apart. Each runner is selected from

the unit located near the next post in the chain, that is, the one to which he is to run. Often the division cavalry furnish these runners.

The chain of runners is under the command of a N. C. O. who is responsible for its efficiency. He has an important task on his hands. He must assure himself that every runner knows, not only his two neighboring posts, but also the general direction of the chain. He must change disabled runners and fill up gaps in his chain. It becomes his duty to instill into the runners the importance of their duty.



EXAMPLE OF A GOOD BARRAGE

Fig. 25

(f) Carrier Pigeons.

Carrier pigeons are the last means of communication. They have been found to give excellent service during heavy shelling or gas attacks. They do not fly very easily at night.

Each command post of a center of resistance in the first line has a pigeon post. These consist of two reliefs of men, four pigeons, and the necessary equipment and food. The pigeons, themselves, have to be relieved every few days. The care given to the birds at the command posts must not be as good as that at the dove cot in the rear, so that when they are released they will return immediately to the latter place, from where the message is delivered to its proper destination.

Poisonous Gas in Warfare

APPLICATION, PREVENTION, DEFENSE, AND MEDICAL TREATMENT.

A Short, Annotated Bibliography of Gases and Kindred Devices Applied in the Present War. Prepared by Henry E. Haferkorn, Engineer School Library, Assisted by Felix Neumann, Surgeon-General's Office Library.

OCTOBER 31, 1917.

PREFATORY NOTE.

The titles entered in this list comprise the latest available material. The military entries are mainly based on the following publications, viz.

Monthly list of Military information carded from books, periodicals, and other sources in the Library, Army War College, Washington Barracks, D. C.

International Military Digest, New York.

Nearly every one of these articles has been examined and annotated when considered necessary.

They include, besides the accounts on Gas Poisoning, also such on kindred devices of modern warfare, as Flame Projectors, Bombs, Incendiary Projectiles, etc.

Titles appearing in brackets, thus [ ], are transcripts of the original language.

The numbers in the Index refer to numbers appearing above each entry of author or title.

The only abbreviations used are the following, viz:

AW: Army War College Library, Washington Barracks, D. C.
CA: U. S. Coast Artillery School Library, Fort Monroe, Va.
ES: Engineer School Library, Washington Barracks, D. C.
LC: Library of Congress, Washington, D. C.
SG: Surgeon-General's Office Library, 7th and B Streets, S. W., Washington, D. C.
IMD: International Military Digest.

The articles from a medical aspect have been kindly supplied by Mr. Felix Neumann, of the Surgeon-General's Office Library. They are not annotated as the titles are comprehensive in nearly every case, and because time was not available for the examination of each individual article. If, however, a new edition of this bibliography should prove desirable, such annotations will be added.

Officers requesting items entered in the Monthly list of the Army War College, will please give number of entry, and date of list, which will be found below the title of each entry filed in the Army War College.—H. E. H.

A. Books.

1

LAKE, B. C.

Knowledge for war. Every officer's handbook for the front. By Capt. B. C. Lake . . . Based on the War Office syllabus of training. London, Harrison & Sons. [1916 (?)] AW.

Gas warfare, p. 105-109. Smoke helmets, p. 107-108. Respirators, p. 108-109. Knapsack sprayers, p. 109.

Monthly List. . . . (Army War College) no. 10. July, 1916. Item no. 177.

2

MOSS, JAMES ALFRED.

Trench warfare. Being a practical manual for training and instruction of officers and men, based on latest information from the battle fronts of Europe. . . Menasha, Wis., G. Banta Pub. Co., c1917.

AW. ES. LC. 24419

Gas warfare, sec. 159-175. Helmets, sec. 166-169. Respirators, sec. 170-171. Knapsack sprayers, sec. 172-174. Liquid fire, sec. 175.

3

SMITH, JOSEPH SHUTER.

Trench warfare. A manual for officers and men. By J. S. Smith, 2d Lieut., with British Expeditionary Force. New York, E. P. Dutton & Co., c1917.

AW. ES. LC. 24416

Gas warfare, p. 113-118. Tear shells, p. 116-118. Gas masks, or respirators, p. 119-121.

4

U. S. NAVY DEPT., BUREAU OF MEDICINE AND SURGERY.

Report of the medico-military aspects of the European war from observations taken behind the allied armies in France. By Surgeon A. M. Fauntleroy, U. S. Navy . . . under the direction of the Bureau of Medicine and Surgery, Navy Dept., Washington, D. C. Washington, D. C., Govt. Print. Off., 1915. vii, 146 p. plates, ports., maps, plans, diagrs. 24cm.

AW. ES. LC. SG. 24421

vii, 146 p. plates, ports., maps, plans, diagrs. 24cm.

Asphyxiating gas, p. 26. Masks, fig. 47.—Gas-bacillus, infection, p. 77—Helmets, p. 121; fig. 180—Bombs, p. 29—Flame projectors, p. 28.

5

VICKERS, LESLIE.

Training for the trenches. A practical handbook. Based upon personal experience during the first two years of the war in France. By Capt. L. Vickers, Late Lieut., Seaforth Highlanders . . . New York, Geo. H. Doran co., c1917. AW. ES. LC. 24418

Chap. ix. Gas and liquid fire, p. 97-100.

6

WALDRON, WILLIAM HENRY.

Elements of trench warfare. Bayonet training. By W. H. Waldron, Capt., 29th U. S. Infantry. New York, Edwin N. Appleton, 1917.

AW. ES. LC. 24415

Chap. ix. Gas warfare, p. 118-127. Helmets, p. 121-124. Respirators, p. 124-126. Knapsack sprayers, p. 126-127.

B. PERIODICALS.

7

ACHARD, C.
Sur l'asphyxie par les gaz toxiques des projectiles de guerre. Académie de Médecine, Paris. Bulletin. 3e série, v. lxxiii, 1915, p. 628-631. SG.

8

AITCHISON, THOMAS.
Gas poisoning. British Medical Journal, London. Sept. 25, 1915, p. 488-489. SG.

Are chlorine gas and nitric peroxide poisonous?

9

ANTIQUITY OF MILITARY ASPHYXIATION. Army and Navy Register, N. Y. v. 57, no. 1819. May 29, 1915, p. 683, 250 words. (Heading: News and comments). AW. CA. LC.

I. M. D., Annual, 1915, p. 33.

10

ASCOLI, M.
Note cliniche sull' avvelenamento da gas asfissianti. Rivista Ospedal., Roma, v. vi, 1916, p. 792-798. SG.

11

ASPHYXIATING GASES. Information, N. Y. v. 1, 1915, p. 25-26. 760 words. ES. LC. 24315

12

ASPHYXIATING GASES. In article: European war. Vatican. Information, N. Y. v. 1, 1915, p. 242. ES. LC. 24315

Relates to Pope Benedict's letter to Cardinal Vannutelli, published in the "Osservatore Romano, the Vatican official organ, on May 26, 1915.

13

ASPHYXIATING GAS IN THE TRENCHES. Review of Reviews, London. v. 56, July 19, 1917, p. 94-95.

14

ASPHYXIATING GASES IN WAR. Birmingham Medical Review, Birmingham, Eng. v. lxxviii, 1915, p. 44-54. SG.

15

ASPHYXIATING GAS IN WARFARE. Nature, London. v. 95, no. 2375. May 6, 1915, p. 267-268. LC.

This is a review of Dr. J. S. Haldane's report on his investigation of the nature and effects of the asphyxiating gases used by the Germans. . . . Professor H. B. Baker accompanied Dr. Haldane. . . .

16

ASPHYXIATING GASES, PROTECTION AGAINST. Information, N. Y. v. 1, 1915, p. 26. 152 words. ES. LC. 24315

Relates to a very cheap apparatus invented by Sir Hiram Maxim.

17

Asphyxiating Gases Used in European War. Army and Navy Gazette, London. Feb. 12, 1916. 400 words. AW. LC.

Heading: The armies. Aircraft fights in the West.
I. M. D., Annual, 1916, p. 64.

18

Aubigny, P. d'

Nouvel explosif de guerre; la thermite. Par P. d'Aubigny, Ingenieur de la Marine. La Revue (ancienne ''Revue des revues''), Paris. xxvi année. vii. série, v. 61, nos. 10, 11. 15 Mai et 1erjuin, 1915, p. 528-531. LC.

Invention of J. Hays Hammond. Incendiary shell, generating prussic acid gas.

19

Bieloff, N. A.

[Poisoning with German asphyxiating gases.] Russkij Vrach, Petrograd. v. xiv, 1915, p. 730-732. SG.

20

Bilancioni, G.

Alterazione anatomiche delle prime vie aeree e digerenti da gas asfissianti. Archivio Italiani Laringologia, Napoli. v. xxxvi, 1916, p. 143-169. 6 plates; the same. Archivio di Farmacologia Sperimentale e Scienze Affini, Rome, Italy. v. xxiii, 1917, p. 3-30. 3 plates. SG.

21

Black, J. Elliot, and others.

Observations of 685 cases of poisoning by noxious gases used by the enemy. By J. Elliot Black, Elliot T. Glenny, and J. W. McNee, lieuts., R. A. M. C., with a note by Col. Sir Wilmot Herringham, British forces in France. Journal Royal Army Medical Corps, London. v. xxiv, 1915, p. 509-516. 4000 words; the same, British Medical Journal, July 31, 1915. SG.

See I. M. D., Annual, 1915, p. 34. Monthly List, (Army War College), no. 2, Nov., 1915. Item no. 181.

22

[Bombs Emitting Asphyxiating Gases Used by Germans in Flanders]. In article: The War in Europe. Army and Navy Journal, N. Y. v. 52, no. 2697. May 1, 1915, p. 1098. 300 words. AW. CA. ES. LC. SG.

Refers to Sir John French's report of the fighting to the north of Ypres. . . . "The chlorine gas . . . contained in steel cylinders," . . .
See also I. M. D., Annual, v. 1, 1915, p. 35.

23

Bonnette, P.

Le casque des tranchées. Presse Médicale, Paris. v. xxiii, annexes, 1915, p. 362-367. SG.

24

Bradford, Sir J. R.

Cases of gas poisoning among the British troops in Flanders. By Sir J. R. Bradford and T. R. Elliott. British Journal of Surgery, Bristol, Eng. v. iii, 1915-16, p. 234-246. SG.

25

BRADWOOD, WAT.
War missiles, ancient and otherwise. The Field, The Farm, The Garden, London. v. 125, no. 3248. March 27, 1915, p. 525-527. LC.

Historical treatise on the use of inflammable matter for ballistics.

26

BRAMWELL, W.
Poultices and venesection in gas poisoning. British Medical Journal, London. v. ii, 1915, p. 460. SG.

27

BROADBENT, WALTER.
Results of German gas poisoning. British Medical Journal, London. Aug. 14, 1915, p. 247-248. SG.

28

BROTHERS IN ARMS—British and French soldiers wearing their poison-gas masks. Sphere, London. v. 63, no. 827, Nov. 27, 1915, p. 217. LC.

Illustration with letterpress, showing respirators worn by soldiers. Reproduction of a photograph.
I. M. D., Annual, 1916, p. 518.

29

BUSINCO, A.
I gas così detti asfissianti in guerra. Rivista di Medicina Legale, Pisa, Italy. v. vi, 1916, p. 305-312. SG.

30

CANARIES IN WARFARE. Literary Digest, N. Y. v. 54, no. 25. (Whole no. 1418). June 23, 1917, p. 1958. LC.

Susceptibility of canaries to detect the presence of gas (carbon monoxid) which is invisible and has no smell.

31

CARPENTER, D. N.
Smoke and powder gases in naval warfare. Military Surgeon, Washington. v. xxxix, 1916, p. 461-473. SG.

32

CHASSEVANT, A.
Traitement des victimes des gaz asphyxiants. Bulletin Générale de Thérapeutique Médicale et Chirurgicale, Paris. v. clxix, 1916-17, p. 29-31. SG.

33

CHLORINE GAS ON THE BATTLEFIELD. Scientific American, N. Y. v. 112, no. 19, May 15, 1915, p. 452. 120 words. AW. CA. ES. LC.

34

CHUGUNOFF, S. A.
[Disturbances on the part of the mental and nervous system after intoxication with the poisonous gases used by the Germans.] Voyenno-Meditsinskij Jurnal, Petrograd. v. ccxlv, Med.-spec. pt., 1916, p. 222-240. SG.

35

A COMBINATION OF PRUSSIC ACID AND ARSENATED HYDROGEN SAID TO BE USED BY GERMANS. The Military Surgeon, Chicago. May, 1916, p. 598. AW. SG.

An abstract of an article published in "Arms and the Man." April 6, 1916. Monthly List, (Army War College), no. 9, June, 1916. Item no. 174.

36

CORMIO, R.

Note cliniche e terapeutiche sull' avvellenamento da gas asfissianti. Policlinico, Roma, v. xxiii, sep. prat. 1916, p. 1231-1234. SG.

37

CORMIO, R.

Note cliniche e terapeutiche sull' avvelenamento da gas asfissianti. Gazetta Medica Lombarda, Milano, Italy. v. lxxvi, 1917, p. 52-55. SG.

38

COW, D.

The effect of atropine in "gassed" patients. Lancet, London. v. i, 1915, p. 1259. SG.

39

COW, D.

Treatment of the symptoms arising from inhalation of irritant gases and vapours. By D. Cow and W. L. Symes. British Medical Journal, London. v. ii, 1915, p. 76. SG.

40

CRABBE.

Report on post-mortem examination of E. R., aged 21, German prisoner of war. Journal Royal Army Medical Corps, London, v. xxvi, 1916, p. 240. SG.

On gas poisoning.

41

CUSHMAN, ALLERTON SEWARD.

The rôle of chemistry in the war. Franklin Institute, Philadelphia, Pa. Journal. v. 181, no. 2, Feb., 1916, p. 163-190. ES. LC.

iv. The rôle of the halogens, p. 186-189.

42

DELAFORCE, E. F.

Weather-cocks. By Lieut.-Col. E. F. Delaforce, R. F. A. The Journal of the Royal Artillery, Woolwich, Eng. v. 43, no. 1, April, 1916. p. 15-17, incl. 2 diagrs., section and elevation. 250 words. AW. CA. ES. LC.

Protection against gas attacks. The "Weather-cock" is an contrivance which may be built from available improvised materials in the field, and warns of approaching gas attacks. I. M. D., Jan., 1917, p. 13.

43

DEVELOPING GAS HELMETS. Army and Navy Register, Washington, D. C. v. 61, no. 1920. May 5, 1817, p. 534. 630 words. AW. CA. LC.

Relates to work undertaken by the U. S. Bureau of Mines, Wash., D. C., for

the construction of a practical gas helmet. W. E. Gibbs, an experienced mechanical engineer has been at work for some time on this problem. Opinions have been sought of Dr. Yandell Henderson, Prof. of physiology in the Yale Medical School and recognized authority on the physiology of respiration, and of J. W. Paul in charge of rescue work.

44

DEVEZE.

Masque contre les vapeurs asphyxiantes. Par Devèze et Orsaud. La Presse Médicale, Paris. v. xxiii, 1915, p. 176. SG.

45

DISPERSING ASPHYXIATING GASES. Scientific American, N. Y. v. 113, no. 5. July 31, 1915, p. 93. 1010 words. 1 half-tone. CA. ES. LC.

Illustration: Fans to disperse asphyxiating gases. A suggestion made by a writer in the "Morning Post," London, and comments on the idea by "Nature."

46

DODGE, WILLIAM D.

Liquid fire and asphyxiating gases. Army and Navy Register, Washington, D. C. v. 60, no. 1876. July 1, 1916, p. 8. AW. CA. LC.

Historical record of the use of liquid fire and asphyxiating gases. Monthly List, . . . (Army War College), no. 11, Aug., 1916. Item no. 123.

47

THE DOUBLE ROLE OF CHLORINE IN WAR. Editorial. Boston Medical and Surgical Journal, Boston. July 1, 1915, p. 23-24. SG.

See I. M. D., Annual, 1915, p. 33.

48

DUJARRIC DE LA RIVIERE, R.

Étude clinique, anatomo-pathologique et histochimique des cas d'intoxications par les gaz irritantes employés par les allemands à Langemarck. Par R. Dujarric de la Rivière et J. Leclercq. La Presse Médicale, Paris. v. xxiii, 1915, p. 253-255; the same, Académie de Médecine, Paris. Bulletin. 3e série, v. lxxiii, 1915, p. 574-576. SG.

Translations of this article were published under following titles, viz: A clinical anatomo-pathological and histo-chemical study of a series of cases of the intoxication produced by the irritant gases employed by the Germans at Langemarck. The Medical Press and Circular, London. New series, C., 1915, p.362-365; and: Lecture on the effects of the gases employed by the Germans. Canada Lancet, Toronto, Ont., v. xlix, 1915, p. 156-166.

49

ELLIOTT, J. H.

The effects of poisonous gases as observed in returning soldiers. By J. H. Elliott and H. M. Towell. The International Journal of Surgery, N. Y. v. xxix, 1916, p. 383-388. SG.

50

EMPLOYMENT OF ASPHYXIATING GAS. Army and Navy Register, Washington, D. C. v. 58, no. 1832. Aug. 28, 1915, p. 269. 900 words. AW. CA. LC.

From Le Temps, Paris, May 9, 1915.
I. M. D., Annual, 1915. p. 35.

51

THE ENEMY ON "PRECEDENTS FOR POISON GAS"! A German disquisition on the history of "chemical attack" in war. Illustrated London News, Lond., v. 147, pt. 1, no. 3981. Aug. 7, 1915, p. 178. 3 illus. AW. LC.

Historical sketch on the use of poison gas in war. Monthly List, (Army War College), no. 1, Oct., 1915. Item no. 116.

52

FERRERO DI CAVALLERLEONE, L.

Gas asfissianti e maschere protettive. Giornale della reale Accademia di Medicina di Torino, Torino, Italy. 4. ser., v. xxi, 1915, p. 356-370. SG.

53

FIGHTING WITH LIQUID FIRE. Literary Digest, N. Y. v. 52, no. 14 (whole 1354). April 1, 1916, p. 924-925. LC.

Describes the "nightmare of smoke and flame" produced by a flammenwerfer attack. The story is told by a wounded corporal of the British territorials, once a New Yorker, whose story was given out in a special cable to the N. Y. Times. His battalion held the trenches just inside Avoncourt Wood.

54

FLAME PROJECTORS. In: Medico-military statistics. Army and Navy Journal, N. Y. v. 53, no. 17. Dec. 25, 1915, p. 527. 1000 words. AW. CA. ES. LC.

Comments on and abstracts from the report on the Medico-military aspects of the European war, by Surg. A. M. Fauntleroy, U. S. N., published under the direction of the Bureau of Medicine and Surgery, Navy Dept.

. . . "Chlorine or bromin gas, compressed in liquid form and liberated from large metal tanks, . . . has caused very distressing deaths," . . .

I. M. D. Annual, 1916, p. 258. Monthly List (Army War College) no. 6, March, 1916. Item no. 249.

55

FLAMEL, NICOLAS.

Torpilles aériennes. La Nature, Paris. v. 43, 2 semestre, no. 2195. Oct. 23, 1915, p. 263-266. 9 half-tones, 2 outline figs. LC.

Fig. 1. Les deux modèles de bombes du canon de tranchée de 58. Fig. 2. Canons de tranchée de 58 prêt à lancer une bombe Dumezil de 45 kilogrammes. Fig. 4. Appareil Moison armé de son projectile à corne. Fig. 5. Canon de 80 de montagne avec sa bombe de 105 kilogrammes. Fig. 6. Broche. Fig. 7. Lanterne. Fig. 8. Bagnette à charger. Fig. 9. Fusée munie de sa bagnette. Fig. 10. Affût trépied pour lancement des fusées. Fig. 11. Fusée de 12 court armée de la bombe de 22.

56

FOY, G.

Poisonous gas. The Medical Press and Circular, London. New ser., v. ciii, 1917, p. 16. SG.

57

FREEMAN, A.

Liquid-fire and poison gas. Living Age, Boston. 8th series, v. 6 (whole 293), no. 3802. May 26, 1917, p. 496-498. LC.

From Chambers's Journal.
Description of apparatus, materials and their application.

58

FREISE.
Ueber vergiftung durch pulvergase. Medicinische Klinik, Berlin. v. xi, 1915, p. 495. SG.

59

[FRENCH ABANDON USE OF LIQUID AIR IN BOMBS AS TOO DANGEROUS.] From Japan Advertiser. Dec. 1, 1916. Clipping filed in Envelope case: Bombs—France—European war. AW.

Monthly List . . . (Army War College), no. 17, Feb., 1917. Item no. 125.

60

GALLO, G.
Osservazioni cliniche su attantadue casi di intossicazione da gas asfissianti in guerra. Giornale di Medicina Militare, Rome, Italy. v. lxiv, 1916, p. 772-804. SG.

61

GALLO, G.
Osservazioni cliniche su 82 casi di intossicazione da gas asfissianti in guerra. La Riforma Medica, Napoli; Roma, Italy. v. xxxiii, 1917, p. 100-104. SG.

62

GARDNER, W. T.
An inclined plane for the treatment of "gassed" cases. Lancet, London. v. ii, 1915, p. 78. SG.

63

GAS AS A WEAPON. Literary Digest, N. Y. v. 50, no. 23, whole no. 1311. June 5, 1915, p. 1323. Illus. LC.

Illus.: British troops equipped with respirators and goggles to resist the German gas.

64

GAS ASFISSIANTI. Rivista Militare Italiana, Roma. Anno lxi, Febb., 1916, p. 220-225. 1500 words. AW.

Signed G. E.

Flamethrowers used by Germans in attacking the advanced French trenches at Malancourt, Feb. 27, 1915, and at Vauquois, March 23, 1915. See I. M. D., Annual, 1916, p. 65.

65

I GAS ASFISSIANTI IN GUERRA; impiego ed effetti; difese e provvedimenti. Rivista d'Igiene e Sanità Pubblica. Parma. v. xxvii, 1916, p. 409-420. SG.

66

OS GASES ASFIXIANTES E OS LIQUIDOS INFLAMAVEIS NA GUERRA ACTUAL. Revista de Artilharia. Lisboa. 13.° ano. no. 145. Julho, 1916, p. 34-45. 3500 words. CA.

Signed F. B.

Asphyxiating gases and inflammable liquids in the present war. I. M. D., Annual, 1916, p. 64.

67

GASES ASFIXIANTES Y PROYECTILES INCENDIARIOS. Memorial de Ingenieros del

Ejército, Madrid. T. 33, no. 3. Marzo, 1916, p. 101-110. 6 outline figs. 3700 words. AW. CA. ES.

Signed: S. F. S.

Asphyxiating gas and incendiary projectiles, methods and devices employed. I. M. D., Annual, 1916, p. 63. Monthly List, (Army War College), no. 10. July, 1916. Item no. 178.

68

GAS IN MILITARY MINES: the symptoms of carbon monoxide poisoning. Hospital, London. v. lx, 1916, p. 169. SG.

69

GAS POISONING IN WAR. Canada Lancet, Toronto, Ont. v. xlviii, 1914-15, p. 641. SG.

70

GAS SOFFOCANTI, GAS VELENOSI E GAS ASFISSIANTI USATI IN GUERRA. Rivista i Artiglieria e Genio, Roma. xxxiii (55a) annata, v. 2, Aprile, 1916, p. 86-88. AW. CA. ES.

A review of the article by V. B. Lewis in the Engineer, London, July 23, 1915, and reference to the idea of Lord Dundonald.

71

LES GAZ ASPHYXIANTS. Annales d'Hygiène publique et de Médecine Légale, Paris. 4e série. v. xxiv, 1915, p. 162-175; the same. Revue Générale de Clinique et de Thérapeutique, Paris. v. xxix, 1915, p. 476-478. SG.

72

LES GAZ ASPHYXIANTS OU DELETERES. 1120 words. Clipping from La France Militaire, Paris. July 15, 1916.—Filed—Envelope case—European war. Monthly List (Army War College), no. 12. Sept., 1916. Item no. 147. AW.

Article signed: Gribeauval.

German use of poison gas methods.

73

GAZES ASPHYXIANTES. Boletin Mensal do Estado do Exercito, Rio de Janeiro, Brazil. vol. xii, no. 2, Agosto, 1916, p. 144-146. 1 plate (3 figs.) 1120 words. AW.

Fig. 1. Tapa-bocca ou mordaça de gazes. Figs. 2, 3. Mascaras de téla tratadas com uma dissolução alcalina.

Asphyxiating gas and masks used for protection against it. Monthly List, (Army War College), no. 14, Nov., 1916. Item no. 119.

74

GERMAN FLAME-PROJECTORS IN USE. French testing flammenwerfer captured from the enemy. Illustrated London News, London. v. 147, pt. 1, no. 3986. Sept. 11, 1915, p. 330-331. 3 illus. AW. LC.

Monthly List . . . (Army War College), no. 2, Nov., 1915. Item no. 169.

75

A GERMAN GAS-ATTACK SEEN FROM THE AIR: a remarkable "snap." Illustrated London News, Lond., v. 147, no. 4000, Dec. 18, 1915, p. 789. AW. LC.

1 illustration with letterpress, reproduced from a photograph.
Monthly List . . . (Army War College), no. 5, Feb., 1916. Item no. 274.

76

German Methods of Trench Warfare. Professional Memoirs, Washington. v. 9, no. 47. Sept.-Oct., 1917. p. 551. AW. CA. ES. LC.

20. Asphyxiating gas. (62 words).

77

German Type of Gas Masks and Helmets Worn During an Attack. Illustrated. Clipping filed in Envelope case: Helmets—Germany—European war. AW.

Monthly List . . . (Army War College), no. 14, Nov., 1916. Item no. 120.

78

German Use of Asphyxiating Gas. Army and Navy Register, N. Y. v. 57, no. 1819. May 29, 1915, p. 675. 550 words. AW. CA. LC.

I. M. D. Annual, 1915, p. 35.

79

German Use of Asphyxiating Gas. The Sphere, London. v. 61, no. 801. May 29, 1915. Illus. p. 202. LC.

Illustrations: How the gas devil comes—"The thick, green mist came rolling towards the parapet."—British soldiers protected against poisonous gas fumes.—The effects of asphyxiating gas on French soldiers.
I. M. D. Annual, 1915, p. 35.

80

The German Use of Asphyxiating Gases. British Medical Journal, London. v. i, 1915, p. 774. SG.

81

[German Use of Poisonous Gas]. The Broad Arrow, London. v. 95, no. 2459, Aug. 13, 1915, p. 185. AW. LC.

Under: Miscellaneous notes. Sir Hiram Maxim's scheme combatting bombs, by throwing of bombs which will set the gas on fire.
Monthly List, (Army War College), no. 1, Oct., 1915. Item no. 121.
An abstract in: Army and Navy Journal, N. Y. v. 52, no. 2714, Aug. 28, 1915, p. 1647. 320 words.
Monthly List . . . (Army War College), no. 1, Oct., 1915. Item no. 120.

82

Goggles, Masks and Bayonets Defying the Enemy Poison Gas. Illustrated London News, Lond., v. 147, pt. 1, no. 3979. July 24, 1915, p. 114. 4 illus. AW. LC.

4 pictures with descriptive letterpress relating to goggles, masks, etc., used as protectors against poison-gas.
Monthly List, (Army War College), no. 1, Oct., 1915. Item no. 119.

83

The Greek-fire of the Germans. Illustrated London News, London. v. 149, pt. 1, no. 4033. Aug. 5, 1916, p. 168. Under Heading: Science jottings. AW. LC.

The constituent parts of Greek fire and how employed.
Monthly List . . . (Army War College), no. 13, Oct., 1916. Item no. 102.

84

HANSEN, N. L.

De kvælende gasarter. Af N. L. Hansen, Kemiker ved Hærens Krudtværk og kemisk konsulent for Hærens tekn. Korps. Dansk Artilleri-tidsskrift, Kjobenhavn, w. Aargang, no. 5. Sept., 1915, p. 194-199. 1850 words. I. M. D., Annual, 1915. p. 33. AW. CA.

. . . "Information as to the chemical composition of the gases is only available in papers and reviews of the Allies, as the Central Powers are silent." . . . Article treats on the component parts of the gas and on means of protection against the same.

85

HEITZ, J.

Sur les troubles cardiovasculaires et l'état du sang dans les intoxications par les gaz asphixiants des allemands. Archives des Maladies du Coeur, des Vaisseaux et du Sang, Paris. v. viii, 1915, p. 447-454. SG.

86

HENDRY, A. W.

Some general notes on suffocation by poisonous gases with detailed notes on one fatal case. By A. W. Hendry and E. L. Horsburgh. British Medical Journal, London. v. i, 1915, p. 964; the same, Journal Royal Army Medical Corps, London. v. xxiv, 1915, p. 374-376. SG.

87

HERLITZKA, A.

Sulla difesa dai gas asfissianti. Giornale della Reale Accademia di Medicina di Torino, Torino, Italy. 4 ser. v. xxi, 1915, p. 277-304. SG.

88

HILL, LEONARD.

Gas poisoning; physiological symptoms and clinical treatment. Journal, Royal Army Medical Corps, London. v. xxvi, 1916, p. 110-121; the same, Lancet, London. Dec. 4, 1915, p. 1248-1249; the same. British Medical Journal, London. Dec. 4, 1915, p. 801-804; 822. SG.

Read before the Medical Society of London.

89

A HISTORY OF THE ASPHYXIATING GAS. The manner in which the Germans employ the gas at the front. Translation. no. 2884. Monthly List. . . . (Army War College), no. 5, Feb., 1916. Item 269. AW.

From sundry articles which have appeared in French journals.

90

A "HONK! HONK!" IN THE TRENCHES MEANS "DON YOUR GAS MASKS!" (Popular Science Monthly, N. Y. v. 90, no. 5, May, 1917, p. 664. 1 illus. 300 words. ES. LC.

Half-tone: "At the approach of poison gas in the trenches a klaxon horn is sounded."

I. M. D., June. 1917, p. 307.

91

HORSES AS WELL AS MEN MASKED AGAINST GAS! A French ammunition team about to enter the danger zone. Illustrated London News, London, v. 150, no. 4064. March 10, 1917, p. 273. AW. LC.

1 picture reproduced from photograph, showing protection of men and beast against gas attacks.

Monthly List . . . (Army War College), no. 20, May, 1917. Item no. 191.

92

HORWOOD, J. G.

The prevention of gas poisoning. British Medical Journal, London. v. ii, 1915, p. 161. SG.

93

HYPO AND STRAW: when the poison-gas cloud is seen. Illustrated London News, London. v. 147, pt. 1, no. 3979, July 24, 1915, p. 103. AW. LC.

Monthly List . . . (Army War College), no. 1, Oct., 1915. Item no. 118. French method for protection against poison gas.

94

IRVINE, LOUIS G.

Gassing accidents from the fumes of explosives. British Medical Journal, London. 1916, v. i. Jan. 20, 1916, p. 162-166. 6500 words. SG.

Asphyxiating gases from mine explosions.

See I. M. D., Annual, 1916, p. 64.

95

KERSHAW, JOHN B. C.

Use of poisonous gases in warfare. How gases are generated and how men may protect themselves from them. By John B. C. Kershaw, F. I. C. Scientific American, N. Y. v. 112, no. 24, June 12, 1915, p. 595-598. Illus. ES. SG.

Fig. 1. Respirator capable of being used with absorbing chemicals. Fig. 2. Two views of a French type of flannel muzzle. Fig. 3. Italian respirator provided with exit valve for exhaled air. [4.] British soldiers prepared to weather a gas attack.

The original of this article was published in Cassier's Engineering Monthly, London. July, 1915, p. 51-56. 2 figs.

96

KOHN-ABREST, E.

Disposif pour l'essai rapide des substances employées contre les gaz nocifs. Académie des Sciences, Paris. Comptes Rendus hebdomadaires des séances. Tome 161, no. 11. Sept. 13, 1915, p. 310-313. 1 outline fig. LC. SG.

97

KOLOSOFF, G. A.

[Symptoms and treatment of poisoning with asphyxiating gases.] Russkiy Vrach, Petrograd. v. xiv, 1915, p. 1065-1071. SG.

98

LESLIE, R. M.
Asphyxiating gases in war. British Journal of Nursing, London. v. lv, no. 3, 1915; Midland Medical Journal, Birmingham, Eng. v. xiv, 1915, p. 115. SG.

99

LESLIE, R. M.
Clinical effects of asphyxiating war gases. American Medicine, Phila., Pa., Burlington, Vt., and N. Y. v. x, 1915, p. 875-882. SG.

100

LEVY, F.
Étude sur le syndrome respiratoire consécutif à l'absorption de gaz asphyxiants. La Presse Médicale, Paris. v. xxiii, 1915, p. 255. SG.

101

LEWIN, L.
Ueber vergiftung durch kohlenoxydhaltige explosionsgase aus geschossen. Münchener Medizinische Wochenschrift, München. v. lxii, 1915, p. 465. SG.

102

LEWIS, VIVIAN B.
Modern munitions of war. iii. Poison gas and incendiary bombs. Illustrated London News, Lond., v. 147, pt. 1, no. 3980, July 31, 1915, p. 140. 4 illus. AW. LC.

German use of poison-gas and its probable components.

Illustrations: British air bomb of small type.—German incendiary bomb dropped during one of the air raids on this country (England).—Showing weight of a gas-essential to its effectiveness in trench warfare. With an outer skin of hemp: a German incendiary bomb dropped in England.

Monthly List (Army War College), no. 1, Oct., 1915. Item no. 117.

103

LEWIS, VIVIAN B.
Modern munitions of war. The Engineer, London. v. 120, no. 3108. July 23, 1915, p. 82-83. 2130 words. ES. LC.

Lecture at the Royal Society of Arts, July 21, 1915, on poisonous gases and bombs.

104

LEWIS, VIVIAN B.
Poison gas and incendiary bombs. Nature, London. v. 95, July 29, 1915, p. 608-609. LC.

Abstract of lecture delivered at the Royal Society of Arts, June 21, 1915.

(In: The Government scheme for the organization and development of scientific and industrial research, iii.)

105

LIQUID FIRE. Clipping from Daily Mail, London. July 1, 1916. Filed in

envelope case: Liquid fire—European war. AW.

Monthly List . . . (Army War College), no. 12, Sept., 1916. Item no. 139.

106

LIQUID FIRE. From Japan Advertiser. Oct. 18, 1916. Clipping filed in Envelope case: Fire—Liquid. AW.

Historical instance of use of liquid fire.
Monthly List . . . (Army War College), no. 16, Jan., 1917. Item no. 140.

107

LIQUIDOS INFLAMABLES. La Guerra y su Preparación, Madrid. tomo i, no. 1, Mayo, 1916, p. 121. 220 words. AW. CA.

From "Rivista Militare Italiana."

108

LIQUIDOS INFLAMMAVEIS. Boletin Mensal do Estado do Exercito, Rio de Janeiro. v. xii, no. 2, Agosto, 1916, p. 146-147. 2 plates (3 figs.) 230 words. AW.

Fig. 4. Maletas para conducção das mascareas. Fig. 5. Lança-bomba Aasen. Fig. 6. Arbalete "Gafanhoto."

109

LOEPER, and others.

La gastrite des soldats asphyxiés. Par Loeper, Peytel and Sabadini. La Presse Médicale, Paris. v. xxiii, 1915, p. 240. SG.

An English translation of the above was published under the title: French clinical lecture on the gastritis of asphyxiated soldiers. Medical Press and Circular, London. New Ser. C., 1915, p. 180-190.

110

LOS LANZA-LLAMAS. Memorial de Artilleria, Madrid. Serie vi, tomo x, p. 118-123. 2 diagrs. 1870 words. AW.

Flame projectors. Notes on the employment of flame projectors. From "Larousse Mensuel Illustré."
Fig. 1. [Showing early type of apparatus]. Fig. 2. [Showing application of flame thrower].
Monthly List . . . (Army War College), no. 12, Sept., 1916. Item no. 141.

111

LOS SERVICIOS SANITARIOS DEL EJERCITO INGLES EN LA GRAN GUERRA. La Guerra y su Preparación, Madrid. tomo i, no. 1, Mayo, 1916, p. 59-91. 14103 words. AW. CA.

Los gases asfixiantes, p. 77, (176 words).

112

LUCHERINI, T.

A proosito dei gas asfissianti. Archivio di farma-cologia sperimentale e Scienze affini, Roma. v. xxii, 1916, p. 429-441. SG.

113

LUNG, G. A.
Asphyxiating gases as a weapon in warfare. The Military Surgeon, Chicago. v. xxxvii, 1915, p. 411-424. SG.

114

McCULLOUGH, J. W. S.
Poisoning by noxious gases. The Canadian Practioner and Review, Toronto, Ont. v. xl, 1915, p. 525-531. SG.

115

McINTIRE, J. T.
Asphyxiating gases. Journal Royal Army Medical Corps, London. v. xxiv, 1915, p. 302. SG.

116

McWALTER, J. C.
The prevention of gas poisoning. British Medical Journal, London. v. ii, 1915, p. 118. SG.

117

MILLER, A. G.
Poisonous gases. British Medical Journal, London. v. i, 1915, p. 1101. SG.

118

MILITARY USE OF SABADILLA IN THE TEAR-PRODUCING GASES. Scientific American, N. Y. v. 115, no. 3, July 15, 1916. 315 words. CA. ES.

Monthly List . . . (Army War College), no. 11, Aug., 1916. Item no. 126.

119

MORAL ASPECTS OF ASPHYXIATION. Literary Digest, N. Y. v. 50, no. 24, June 12, 1915. 2 illus. LC.

Illus.: Dutch and German cartoonists air their views on gas.

120

MORTIMER, J. D.
The treatment of gas poisoning. Lancet, Lonodn. v. i, 1915, p. 1262; the same, Medical Press and Circular, London. New ser. v. xcix, 1915, p. 566. SG.

121

MOTT, F. W.
Punctiform haemorrhages of the brain in gas poisoning. British Medical Journal, London, no. 2942. May 19, 1917, p. 637-641. 8 illus., 1 plate. SG.

122

MUNITIONS OF THE PRESENT WAR. Railway Review, Chicago. v. 57, no. 12. Sept. 18, 1915, p. 373-376. LC.

Poisonous gases and incendiary bombs, p. 375-376.

123

Neue Franzoesische Gasbombe. Artilleristische Monatshefte, Berlin. no. 102. Juni, 1915, p. 343. 150 words. AW. CA.

Heading: Verschiedenes.

New French gas bombs. Frankfurter Zeitung, Mai 28, 1915, quoting a report of the London Times.

I. M. D. Annual, 1915, p. 34.

124

New German Devices. Shells filled with liquid poison. Field Artillery Journal, Washington. v. 7, no. 3. July-Sept., 1917, p. 347-348. 363 words. AW. CA. ES.

[Chap.] "Current field artillery notes."

Relates to devices used by the Germans on the French town Armentières, near the Belgian frontier.

125

Nicolski, D.

[Construction of a museum of the means against the action of asphyxiating gases.] Russkiy Vrach, Petrograd. v. xiv, 1915, p. 738. SG.

126

Notes on Methods to be Adopted to Meet Asphyxiating Gases. How to use the respirator. Filed pocket card—Gases—European war, 1914-15. Monthly List. . . . (Army War College), no. 2, Nov., 1915. Item no. 182. AW.

127

Ohnesorg, K.

Intoxication by detonation and explosion gases aboard ship. United States Naval Medical Bulletin, Washington. v. x, 1916, p. 625-633. SG.

128

Otter, C. G. von

Kväfvande gaser som stridsmedel. Artilleri-Tidskrift, Upsala, Sweden. v. 46, parts 1-2, 1917, p. 69-80. 3450 words. CA.

Gases as instruments of warfare.

I. M. D., Sept., 1917, p. 500.

129

Parker, Rushton, and others.

Poisonous gases. By Rushton Parker, J. D. Mortimer, W. S. Syme, and Harry Campbell. British Medical Journal, London. June 12, 1915, p. 1016, 1027-1028; June 19, 1915, p. 1065-1066. SG.

Editorial and letters.

130

Pascal, Pierre.

La lutte contre les gaz asphyxiants de l'armée allemande. Le Génie Civil, Paris. v. 66, no. 24, June 12, 1915. p. 377-380. 1 diagr. ES. LC.

Extracts under the title: Combatting asphyxiating gases, have appeared in: *The Engineer, London. v. 119, June 18, 1915, p. 598; *Engineering Magazine, N. Y. v. 50, no. 1, Oct., 1915, p. 114-116.

Nature of asphyxiants and means available, and employed in the present war, for rendering them innocuous.

131

PELLEGRINI, R.

Sui gaz asfissianti usati in guerra; considerazioni ed osservazioni personali. Pensiero Medico, Milano. v. vi, 1916, p. 493; 505; 517. SG.

132

PELLEGRINI, R.

Sulle lesioni anatomopatologiche da gaz asfissianti. Il Morgagni, Napoli; Milano. v. lviii, pt. 1, 1916, p. 297-309. SG.

133

PICCININI, P.

Per la difesa dei gas asfisstanti. Gazzetta Medica di Roma, Roma. v. xliii, 1917, p. 30-35. SG.

134

PIERI, G.

L'intossicazione da gas asfissianti (cloro). Rivista Ospedaliera, Roma, Italy. v. v, 1915, p. 542-549. SG.

135

PISANÒ, G.

Contributo alla conoscenza dell' azione tossica dei gas velenosi usati dagli Austro-Tedeschi. Gazzetta degli Ospedali e delle Cliniche, Milano, Italy. v. xxxvii, 1916, p. 1521. SG.

136

PLANTS AND ASPHYXIATING GASES. Scientific American Supplement, N. Y. v. 83, no. 2148. March 3, 1917, p. 132. 240 words. CA. ES. LC.

Deals with the effect of deleterious gases on plants in and near the fighting line.

137

POISONOUS GASES. British Medical Journal, London. v. i, 1915, p. 1016. SG.

138

POISONOUS GASES AT THE FRONT. Medical Magazine, London. v. xxiv, 1915, p. 191. SG.

139

POISONOUS GASES IN WAR. The Journal of State Medicine, London. v. xxiii, 1915, p. 219. SG.

The same title: Canada Lancet, Toronto, Ont. v. xlviii, 1915, p. 545-547.

140

PURVIS, J. E.

Asphyxiating gasses. Cambridge Review, Cambridge, Eng. May, 1915, p. 325-326.

A chemist's comment on the manufacture and employment of such gases.

141

RAHENA, F.

Los gases asfixiantes como arma de la presente guerra Europea. Revista Valenciana de Ciencias Hédicas, Valencia, Spain. v. xviii, 1916, p. 113. SG.

142

RATHERY, F.

Les accidents occasionnés par les gaz toxiques dits asphyxiants employés par les allemands. Étude clinique, anatomo-pathologique et thérapeutique. Paris Medical, Paris. v. xvii, 1915-16, p. 389-394. SG.

143

RENSHAW, A.

Post-mortem appearances of septicaemia resulting from "gas poisoning" and their relations to anti-typhoid inoculation statistics. Journal Royal Army Medical Corps, London. v. xxiv, 1915, p. 591-593. SG.

144

RESPIRATORS. Information, N. Y. v. 1, 1915, p. 503. 210 words. ES. LC.

French gas mask adopted, described from an article of "La Nature," Paris, May 22, 1915.

145

RHO, F.

Avvelenamento per gas derivanti dagli esplosivi sulle navi da guerra. Annali di Medicina Navale, Roma. v. ii, 1916, p. 336-343. SG.

146

ROBERTS, A. A.

La chimie sur le front. Gaz asphyxiants et liquides enflammés. La Science et la Vie, Paris, v. viii, no. 22. Août et Sept., 1915, p. 243-523. 20 illus., 4 outline figs. 4500 words. AW. LC.

Illustrations show flame projectors, their construction and application also the various means for protection against gas attacks, viz: Masks, helmets, respirators, etc.

Monthly List . . . (Army War College) . . . no. 5, Feb., 1916. Item no. 356.

147

SADOVSKI, P. P.

[Poisoning with asphyxiating gases en masse.] Sibirskiy Vrach, Tomsk, Siberia. v. ii, 1915, p. 189-191. SG.

148

La Seconda Battaglia di Ypres. I gas asfissianti ed i cannoni tiranti a 30 chilometri. Rivista di Cavalleria, Pinerolo, Italy. Anno xviii. Fascicolo xi. 15 Novembre, 1915, p. 421-433. 3600 words. AW.

Signed: x.

The second battle of Ypres. "Asphyxiating gases and guns of 30 kilometer range conquered on a battle field for the first time at 5 p. m. on April 22, 1915, when the Germans attacked a French division . . . "I. M. D., Annual, 1915, p. 64.

149

Sergent, É.

Note sur quelques effets cliniques des gaz asphyxiants. Par É. Sergent at A. Agnel. Société Médicale des Hôpitaux de Paris, Paris. Bulletins et Mémoires. 3e série. v. xxxix, 1915, p. 960-964. SG.

150

Serono, C.

I gas asfissianti e tossici adoperati in guerra e la difesa contro di essi. Di C. Serono e E. Trocello. Annali i Medicine Navale, Roma. v. i, 1915, p. 550. 562. The same. Archivio di farmacognosia e Scienze Affini, Roma. v. iv, 1915, p. 167-174. SG.

151

Sisto, P.

L'avvelenamento per gas asfissianti. La Riforma Medica, Napoli; Roma, v. xxxii, 1916, p. 1234; 1265; 1290. SG.

152

Skvortsoff, V. I.

[Treatment of those poisoned with asphyxiating gases.] Russkiy Vrach, Petrograd. v. xiv, 1915, p. 793. SG.

153

Snively, H. H.

A national guardsman on the Galician front. By Major H. H. Snively, Medical Corps, Ohio National Guard. National Guard Magazine, Columbus, O. v. 13, no. 7, July, 1916, p. 132-133; 140-141. AW. ES.

Monthly List . . . (Army War College), no. 11, Aug., 1916. Item no. 125. Describes, on page 132, first column, constituents of solution used by Russians for saturating masks against poison gases.

154

Sobre Gases Asfixiantes. La Guerra y su Preparación, Madrid. tomo i, no. 1, Mayo, 1916, p. 114-119. 4 figs. 1300 words. AW. CA.

"De datos facilitados por testigos presenciales de la lucha en el frente y por los tentientes coroneles D. Julio Vicéns y D. José Rodriguez de la Riva."

Illustrations show masks and respirators worn by soldiers, and pouches in which they are carried.

I. M. D., Annual, 1916, p. 62-64.

155

Spraying Liquid Fire: The German "flammenwerfer" in action. Illustrated

London News, Lond., v. 147, part 1, no. 3983, Aug. 21, 1915, p. 253.
AW. LC.

Picture, drawn by A. Forestier from material supplied, with descriptive letterpress, on the German flame projector used in attacks on trenches.

Monthly List . . . (Army War College), no. 1, Oct., 1915. Item no. 108.

156

Suffocating Gases and their Antidotes. Scientific American Supplement, N. Y. v. 82, no. 2115. July 15, 1915, p. 36. 490 words. CA. ES. LC.

Abstract of an address of an Italian chemist, Signor Guareschi, before the Chemico-Tech. Society, Turin, Italy.

157

Suffocating the Enemy. Literary Digest, N. Y. v. 50, no. 19, March 8, 1915, p. 1063. 2100 words. LC.

Newspaper comments on this new mode of offense.

Sir James Dewar, P. R. I., is quoted as saying that the Germans undoubtedly have hundreds of tons of chlorine available, that they have been manufacturing it for years in tremendous quantities.

I. M. D., Annual, 1915, p. 34.

158

Sundell, C. E.

The clinical manifestations of gas in military mines. Lancet, London. v. i, 1916, p. 957. SG.

159

Symons, C. H.

Poisoning by gasses from explosives. Journal of the Royal Medical Service, London. v. ii, 1916, p. 513-516. SG.

160

Tengely, Ida C.

The use of atropine in gassed patients. Lancet, London. v. i, 1915, p. 1203. SG.

161

Teyñac, A.

Sur un cas d'asphyxie multiple et compliquée observé sur le front. Contribution à l'hygiène des transports militaires automobiles. Journal de Médicine de Bordeaux, Bordeaux, France. v. xlvi, 1916, p. 107-111. SG.

162

Throwing Liquid Fire. One of the novel weapons brought forth by the war. Scientific American Supplement, N. Y. v. 81, no. 2112. June 24, 1916, p. 405. 1 illus., 4 sections, 1 outline fig.; Literary Digest, N. Y. v. 53, no. 5, (whole 1371), July 29, 1916, p. 246. Title: Liquid fire as a weapon. Same illus. AW. LC. ES.

Monthly List (Army War College), no. 11, Aug., 1916. Item no. 118.

Illustrations: Operating a flame projector in a German trench. Fig. 1. Early type of "flammenwerfer." Flame deflected by a shield. Fig. 2. Improved

type with attached ignition jet. Fig. 3. Improved apparatus with separate ignition jet. Fig. 4. How the device is fed from a protected reservoir. Fig. 5. Portable apparatus for projecting flames.

163

TILDEN, WILLIAM AUGUSTUS.

Poisonous gases in warfare and their antidotes. Nature, London. v. 95, no. 2380. June 10, 1915, p. 395-397. 2 figs. (outline cuts). LC.

Abstract in: *Engineering Magazine, N. Y. v. 49, no. 5, Aug., 1915, p. 739. 700 words. ES. LC.

Elements and compounds which the Germans made use of, and means for combatting them.

164

[TILSON, JOHN Q.]

Gases in warfare. Congressional Record, Washington, D. C. June 27, 1917, p. 4761. AW. LC.

Colonel John Q. Tilson's lecture before Congress. History of the use of gas in warfare. Methods used in the European war. Gas bombs from aircraft. Defense against gas.

165

TILSON, JOHN Q.

Gases in warfare. By Colonel John Q. Tilson. Infantry Journal, Washington. v. 14, no. 2, Aug. 1917, p. 108-117. 5520 words. AW. CA. ES. LC.

Extracts from speech in House of Representatives, June 27, 1917.

166

TOURNEMAIN, ALFRED.

Les projectiles de tranchées: bombes, grenades, pétards et torpilles. Science et la Vie, Paris, t. 8, no. 23, Oct., Nov., 1915, p. 546-554. 13 illus., 1 diagr. AW. LC.

167

TRAITEMENT DES MALADES ATTEINTS PAR LES GAZ ASPHYXIANTS. Clipping from La France Militaire, Paris. Dec. 14, 1915. Filed Pocket card—Gas—European war. Item no. 273. Monthly List (Army War College). no. 5, Feb., 1916. AW.

Course of treatment in French army for men suffering from effects of poison gas.

168

TREMOLIERES, F.

Effets des gaz irritants des projectiles de guerre. Par F. Trémolières et P. Loew. Société Médicale des Hôpitaux de Paris, Paris. 3e série. v. xxxix, 1914, p. 597-600. SG.

169

UNLAWFUL WARFARE. Candid Quarterly Review of Public Affairs, London. v. 4, no. 7. Aug., 1915, p. 559-571. LC.

Reprint from "The Panmure papers," by Sir Geo. Douglas and Sir Geo. Dalhousie Ramsay, Lond., Hodder & Houghton, 1908.

Admiral Lord Dundonald's plan for the use of sulphurous acid gas.

From p. 562. ". . . The great admiral Lord Dundonald—perhaps the ablest sea captain ever known, not even excluding Lord Nelson—was also a man of wide observation, and no mean chemist. He had been struck in 1811, by the deadly character of the fumes of sulphur in Sicily; and when the Crimean war (1855) was being waged, he communicated to the English government, then presided over by Lord Palmerston, a plan for the reduction of Sebastopol by sulphur fumes. The plan was imparted to Lord Panmure and Lord Palmerston, and the way in which it was, is so illustrative of the trickery and treachery of the politician that it is worth while to quote Lord Palmerston's private communication upon it to Lord Panmure:" . . .

. . . ."Lord Dundonald also contemplated floating naphtha on the water, and igniting it by means of a ball of potassium. The uncertainty of the wind condemned his plans."

170

THE USE OF ASPHYXIANTS IN WARFARE. Nature, London. v. 95, no. 2374. April 29, 1915, p. 234. LC.

171

THE USE OF POISONOUS GASES IN WARFARE. The Medical Magazine, London. v. xxiv, 1915, p. 296-298. SG.

172

VERSHININ, N. V.

[Poisoning with asphyxiating gases.] Sibirskiy Vrach, Tomsk, Siberia. v. ii, 1915, p. 231. SG.

173

VERWENDUNG BETAEUBENDER GASE. Medicinische Blätter, Wien. v. xxxvii, 1915, p. 172; 184. SG.

174

VICTORIA, CARLOS.

La guerra moderna. Los gases asfixiantes o deletéreos. Memorial de Caballeria, Madrid. Año i, num. 3, Sept., 1916, p. 257-260. 1400 words. 2 illus. Army Service Schools Lib.

Illus. [Fig. i] Mascarilla usada en el ejército inglés. [Fig. ii] Mascarilla reglamentaria en el ejército francés. . . . "Gas was employed by the Germans for the first time, near Ypres, on 22 April, 1916, in preparing for the attack against the sector Steenstraate-Langemark." . . . Article gives the composition, and effect of the gas, as well as means of protection against the same.

See I. M. D., Jan., 1917, p. 13.

175

VISHEGORODSKAYA, YE. S.

[Cases of nervous disturbances in poisoning with German asphyxiating gases.] Psikhiatricheskaya Gazeta, Petrograd. v. ii, 1915, p. 275. SG.

176

WAINWRIGHT, LENNOX.

What is the gas? Lancet, London. July 24, 1915, p. 198. SG.

177

WAR BY POISON. The Spectator, London. v. 114, no. 4532. May 8, 1915, p. 642-643.

On gas poisoning.

178

YABLONSKI, YE. K.

[Apparatus for giving aid to those poisoned with gases, or found in a state of asphyxia.] Morskoĭ Vrach, Petrograd. 1915, p. 280-296. SG.

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NUMBERS REFER TO NUMBERS ABOVE THE AUTHORS' NAME, OR ABOVE THE FIRST WORD OF THE TITLE.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Soc. C. E. P.=American Society of Civil Engineers, N.Y. Proceedings.

Am.Soc.C.E.T.=American Society of Civil Engineers, N. Y. Transactions.

A.P.C.=Annales des Ponts et Chaussées, Paris.

A. R.=The Army Review, London.

Assoc'n E. S.=Association of Engineering Societies, St. Louis, Mo. Journal.

B.Eng.C.=Brooklyn Engineers' Club, Brooklyn, N. Y. Proceedings.

Ca.E.=Canadian Engineer, Toronto, Can.

Ca.S.E.=Canadian Society of Civil Engineers (Montreal), Transactions.

Cem. E.=Cement Era, Chicago.

Conn.S.C.E.=Connecticut Society of Civil Engineers, New Haven, Conn. Papers and Transactions.

Con.=The Contractor, Chicago.

De Ing.=De Ingenieur Hague, Holland.

Engi.=The Engineer, London.

Eng.=Engineering, London.

Eng.C.=Engineering and Contracting, Chicago.

Eng.M.=Engineering Magazine, N.Y.

Eng.N.=Engineering News, N. Y.

Eng. R.=Engineering Record, N. Y.

Eng.C.P.=Engineers' Club of Phila. Proceedings.

Eng.S.P.=Engineers' Society of Pennsylvania. Harrisburg. Journal.

Eng.S.W.P.=Engineers' Society of Western Penn'a. Pittsburg, Pa. Proceedings.

Inst.C.E.=Institution of Civil Engineers, London. Minutes of Proceedings.

Inst.Eng.Sh.=Institute of Engineers and Shipbuilders in Scotland, Glasgow. Transactions.

Int.R.=Internationale Revue über die gesamten Armeen und Flotten, Dresden.

J.R.Art.=Journal of the Royal Artillery, Woolwich, England.

J.U.S.Art.=Journal, U. S. Artillery, Fort Monroe, Va.

K.T.=Kriegstechnische Zeitschrift, Berlin.

Mu.E.=Municipal Engineering, Indianapolis, Ind.

Prof.M.=Professional Memoirs, Corps of Engineers and Engineer Dept. at Large, U. S. A. Washington.

R.Art.=Revue d'Artillerie, Paris.

Rev.G.=Revue du Génie Militaire, Paris.

R.Eng.J.=Royal Engineers Journal, Chatham, England.

R.U.S.I.J.=Royal United Service Institution, London. Journal.

Sci.Am.=Scientific American, N. Y.

Sci.Am.S.=Scientific American Supplement, N. Y.

Soc.Eng.=Society of Engineers, London. Transactions.

Tech.M.=La Technique Moderne, Paris.

U.S.Nav.I.=U. S. Naval Institute, Annapolis, Md. Proceedings.

W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 43, Jan.-Feb., 1916.)

BANK PROTECTION. (Rivers.)

New type of mattress used for river bank protection. A. C. Everham. (Eng. N.), Nov. 30, 1916. 1220 words. 2 half-tones, 1 diagr.—Results of experiments looking to the development of a form of subaqueous concrete revetment for the protection of river banks against scour or erosion. E. M. Markham. (Prof. M.), Nov.-Dec., 1916. 4128 words. 8 half-tones.

BARGES.

Concrete barges stand test. (Eng. N.), Nov. 16, 1916. 280 words.

CANALS—France.

Tunnel for Marseilles canal, largest in world. (Eng. N.), Nov. 30, 1916. 890 words. 3 half-tones.

CANALS—Great Britain.

The Forth and Clyde canal. (Engi.), Nov. 3, 1916. 1240 words.

CANALS—Sweden.

De opening van het Trollhättankanaal. H. A. Van Ijsselsteyn. (De Ing.), Oct. 21, 1916. 2720 words. 2 half-tones, 2 maps, 2 diagrs.

CANALS—Towing.

Canal haulage. J. W. White. (Engi.), Nov. 3, 1916. 360 words.

CANALS—United States. (See also Panama Canal.)

The New York Barge canal. Its relation to other waterways and outlying territory. (Sci. Am. S.), Nov. 18, 1916. 2952 words.

CEMENT-CONCRETE.

Bad effects resulting from the use of salt water in reinforced concrete structures built in tropical countries. (Eng. C.), Nov. 22, 1916. 2800 words. 4 half-tones.—Chuting concrete over extended areas. (Contracting), Nov., 1916. 1360 words. 1 half-tone, 1 diagr.—Concrete barges stand test. (Eng. N.), Nov. 16, 1916. 280 words.—Concreting in cold weather. (Con.), Nov. 1, 1916. 1500 words. 2 diagrs.—Concrete-revetment machine for the Mississippi E. M. Markham. (Eng. N.), Dec. 7, 1916. 2950 words. 5 half-tones, 1 diagr. Concrete wharf supports in salt water. T. S. Williams. (Ca. E.), Nov. 2, 1916. 3125 words.—Famous Yadkin development nearing completion. (Eng. N.), Nov. 16, 1916. 2760 words. 3 half-tones, 1 plan, 2 diagrs.—Laying concrete in freezing weather; Troy lock and dam. D. A. Watt. (Prof. M.), Nov.-Dec., 1916. 516 words.—Pneumatic mixer lines railway tunnel under traffic. (Eng. N.), Nov. 16, 1916. 145 words, 4 half-tones, 1 diagr.—A reservoir that will float. J. F. Springer. (Sci. Am.), Dec. 2, 1916. 1600 words. 3 half-tones.—Sand streaks in concrete. D. A. Watt. (Prof. M.), Nov.-Dec., 1916. 504 words.—Submarine mine wharf at Fort Armstrong. C. J. Taylor. (Prof. M.), Nov.-Dec., 1916. 2628 words. 5 half-tones.

COLUMBIA RIVER.

Improvement of the mouth of the Columbia River. G. Bagnall. (Prof. M.), Nov.-Dec., 1916. 13296 words. 9 half-tones, 3 fold. plates.

CONCRETE BARGES.

Concrete barges stand test. (Eng. N.), Nov. 16, 1916. 280 words.

CONCRETE—Seawater.

Bad effects resulting from the use of salt water in reinforced concrete

structures built in tropical countries. (Eng. C.), Nov. 22, 1916. 2800 words. 4 half-tones.—Concrete wharf supports in salt water. T. S.Williams. (Ca. E.), Nov. 2, 1916. 3125 words.—Saltwater causes cracking concrete in Philippines. (Eng. N.), Nov. 30, 1916. 520 words.

CONVEYORS.

The Donald portable elevator-conveyor. (Eng.), Nov. 24, 1916. 2349 words. 1 half-tone, 7 diagrs., 4 cross-sections.

COFFER-DAMS.

Improvement of Livingstone Channel, Detroit River, dry excavation. C. Y. Dixon. (Prof. M.), Nov.-Dec., 1916. 2456 words. 1 diagr.

COST-KEEPING.

Conversion factors in cost keeping as an aid to management. H. P. Gillette. (Eng. C.), Nov. 29, 1916. 896 words.—Cost keeping methods for concrete construction. (Eng. C.), Nov. 22, 1916. 2000 words.—Cost records of drafting and engineering. (Eng. C.), Nov. 29, 1916. 1040 words. Tables.

CRIBS.

A useful type of cribwork. A. E. Eastman. (Ca. E.), Nov. 23, 1916. 1018 words. 1 cross-section.

DAMS.

Famous Yadkin development nearing completion. (Eng. N.), Nov. 16, 1916. 2760 words. 3 half-tones, 1 plan. 2 diagrs.—Outlet control of Elephant Butte dam. F. Teichman. (Eng. N.), Nov. 30, 1916. 2790 words. 2 diagrs. —Repair of the Tres Cruses dam, Cavite province, P. I. C. R. Bennett. (Eng. N.), Nov. 30, 1916. 1430 words. 1 half-tone, 1 diagr.

DETROIT RIVER.

Improvement of Livingstone Channel, Detroit River, dry excavation. C. Y. Dixon. (Prof. M.), Nov.-Dec., 1916. 2456 words. 1 diagr.

DIKES.

Draining North Holland after January's great flood. J. Spaander. (Eng. N.), Oct. 26, 1916. 3090 words. 10 half-tones, 1 map, 2 sections, 3 diagrs.—Historic-technical investigation of our dikes. (Historisch. technisch onderzoek van onze dijken door A. Groothoff. (De Ing.), Sept. 30, 1916. 940 words.—A project for enclosing the Zuider Sea by dikes in reinforced concrete. (Een ontwerp voor den afsluitdijk der Zuiderzee in gewapend beton door C. Wolterbeek. (De Ing.), Sept. 23, 1916. 10130 words. 3 sections, 6 diagrs.—Cracking and shifting of seadikes and means to prevent the same. (Scheuren en afschuivingen van zeedijken en een middle om deze te voorkomen.) De Ingenieur, Oct. 14, 1916. 2210 words.

DRAINAGE. (See also Dikes.)

Building 600 miles of drainage ditches. (Eng. N.), Oct. 19, 1916. 824 words. 6 half-tones, 1 plan, 1 section, 1 diagr.—Economical method of cross-sectioning drainage ditches. B. F. Burns. (Eng. C.), Nov. 29, 1916. 560 words. 1 cross-section.

DREDGES AND DREDGING. (See also Detroit River.)

Combination hydraulic and dipper dredge. (Eng. C.), Oct. 18, 1916. 128

words. 1 diagr.—Constructing Port Newark terminal, N. J. (Contracting), Nov., 1916. 3300 words. 5 half-tones, 1 diagr.

ENGINEER TROOPS——Prussia.

Los Cuerpos de zapadores y de ingenieros en Prussia. (Memorial del ing.), Sept., 1916. 5220 words.

EROSION. (See Bank Protection.)

EXCAVATION AND EXCAVATORS.

Methods and costs of dragline excavation. J. A. Barr. (Con.), Nov. 15, 1916. 224 words. 1 diagr.

EXPLOSIVES.

Thawing explosives. (Ca. E.), Oct. 19, 1916. 1484 words. 2 diagrs.

FLOODS AND FLOOD CONTROL.

The battle over the Miami flood-prevention plans. H. M. Chittenden. (Eng. N.), Nov. 9, 1916. 273 words. 1 diagr.—Southern floods and their forestry lessons. H. H. Chapman. (Am. Forestry), Aug., 1916. 1541 words. 8 half-tones.—Southern rains and floods of July, 1916, exhibited. (Eng. N.), Nov. 9, 1916. 1370 words. 6 diagrs.

FOREST INFLUENCES.

Southern floods and their forestry lessons. H. H. Chapman. (Am. Forestry), Aug., 1916. 1541 words. 8 half-tones.

FORTIFICATIONS.

Nature of fortifications which may be encountered in field warfare and artillery means and methods of attacking such works. J. R. Davis. (Field Art. J.), July-Sept., 1916. 9470 words.

FORT ARMSTRONG.

Submarine mine wharf at Fort Armstrong. C. J. Taylor. (Prof. M.), Nov.-Dec., 1916. 2628 words. 5 half-tones.

HANDLING MATERIALS.

Appliances for handling materials at Ports. Sir J. P. Griffith. (Engi.), Nov. 3, 1916. 5940 words.

HARBORS—Canada.

Canadian terminal harbors on the Great Lakes. (Ca. E.), Oct. 12, 1916. 552 words. 1 map.

HARBORS—France. (See also Marseille-Rhône canal.)

Les ports français et la guerre. Saint-Nazaire. A. Pawlowski. (Le Génie Civil), Nov. 11, 1916. 3850 words. 3 half-tones, 1 diagr.—The same, La Rochelle-La Pallice. A. Pawlowski. (Le Génie Civil), Oct. 7, 1916. 4810 words. 2 half-tones, 3 diagrs.—The same. Nantes et la Loire maritime. A. Pawlowski. (Le Génie Civil), Nov. 4, 1916. 5410 words. 3 half-tones, 5 diagrs.

HYDRAULICS.

Velocity coefficients for a dredged drainage canal. P. V. Hodges. (Eng. N.), Nov. 30, 1916. 1160 words. 1 half-tone. 4 cross-sections.

HYDRO-ELECTRIC PLANTS. (See Yadkin Narrows dam.)

JETTIES. (See Columbia River.)

KENTUCKY RIVER.

Retaining wall failure at Lock no. 13, Kentucky River. H. G. McCormick. (Prof. M.), Nov.-Dec., 1916. 4512 words. 3 half-tones, 1 fold. plate.

LEVEES.

Constructing Port Newark terminal, N. J. (Contracting), Nov., 1916. 3300 words. 5 half-tones, 1 diagr.—Moving 5000000 Dollars worth of dirt on Vincennes, Ind., levee job. (Con.), Nov. 1, 1916. 1940 words. 5 half-tones, 2 diagrs.

LIGHTHOUSES.

Barge canal lighthouses. (Barge Canal bull.), Nov., 1916. 2145 words.—The U. S. Lighthouse service. I. Its history, growth, and methods. (Sci. Am. S.), Nov. 25, 1916. 4833 words. 11 half-tones, 2 diagrs.

LIVINGSTONE CHANNEL. (See Detroit River.)

LOCKS AND LOCK GATES.

Large modern lock gates. M. Elliott. (W. S. E. J.), Oct., 1916. 15950 words. 1 half-tone, 2 cross sections, 3 diagrs., 2 fold. plates.—Laying concrete in freezing weather; Troy lock and dam. D. A. Watt. (Prof. M.), Nov.-Dec., 1916. 516 words.

MARSEILLE-RHONE CANAL.

Tunnel for Marseilles canal, largest in world. (Eng. N.), Nov. 30, 1916. 890 words. 3 half-tones.

MATTRESSES.

Concrete revetment machine for the Mississippi. E. M. Markham. (Eng. N.), Dec. 7, 1916. 2950 words. 5 half-tones, 1 diagr—Draining North Holland after January's great flood. J. Spaander. (Eng. N.), Oct. 26, 1916. 3090 words, 10 half-tones, 1 map. 2 sections, 3 diagrs.—New type of mattress used for river-bank protection. A. C. Everham. (Eng. N.), Nov. 30, 1916. 1220 words. 2 half-tones, 1 diagr.

MILITARY ENGINEERING.

Military engineering. Col. G. A. Zinn. (Eng. C. P.), Aug., 1916. 13176 words

MOTOR TRUCKS.

Adaptability of motor transportation for field artillery use. J. E. McMahon, jr. (Field Art. J.), July-Sept., 1916. 6650 words. 20 half-tones.—Petrol caterpillar tractor and train. (Engi.), Nov. 17, 1916. 940 words. 3 half-tones, 1 diagr.

PANAMA CANAL.

General Goethals on the Panama canal slide critics. (Eng. N.), Nov. 23, 1916. 4240 words.—Terminal facilities of the Panama Canal. H. H. Rousseau. (U. S. Nav. I.), Nov.-Dec., 1916. 11200 words. 3 half-tones, 5 fold. plates.

PHOTOGRAPHIC SURVEYING.

Photogrammetry for taking topography of watershed. D. H. Nelles. (Eng. N.), Nov. 9, 1916. 1900 words. 1 diagr.

PIERS. (See Wharves.)

PILE DRIVERS AND PILE DRIVING.

Revolving pile driver. (Eng. C.), Nov. 15, 1916. 464 words. 1 half-tone.

POLLUTION OF WATERS.

Proposed code for the sanitary control of waterways. (Eng. N.), Nov. 9, 1916. 1200 words.

PUBLIC SERVICE REGULATIONS.

Public service regulations. J. L. Schley. (Prof. M.), Nov.-Dec., 1916. 7428 words.

RETAINING WALLS.

Retaining wall failure at lock no. 13, Kentucky River. H. G. McCormick. (Prof. M.), Nov.-Dec., 1916. 4512 words. 3 half-tones, 1 fold. plate.

REVETMENTS.

Concrete-revetment machine for the Mississippi. E. M. Markham. (Eng. N.), Dec. 7, 1916. 2950 words. 5 half-tones, 1 diagr.—Results of experiments looking to the development of a form of subaqueous concrete revetment for the protection of river banks against scour or erosion. E. M. Markham. (Prof. M.), Nov.-Dec., 1916. 4128 words. 8 half-tones.

RIVER ENGINEERING. (See also Detroit River.)

Retaining wall failure at lock no. 13, Kentucky River. H. G. McCormick. (Prof. M.), Nov.-Dec., 1916. 4512 words. 3 half-tones, 1 fold. plate.

ROCK EXCAVATION. (See also Detroit River.)

Enormous deep-water piers at Halifax. I. (Contracting), Nov., 1916. 590 words. 3 half-tones. The same. II. (Contracting), Dec., 1916. 900 words. 5 half-tones.

SEARCHLIGHTS.

A device for giving an image of the searchlight arc in full size outside the searchlight drum. Capt. A. Gibson. (J. U. S. Art.), Nov.-Dec., 1916: 670 words. 3 half-tones, 1 diagr.—Modern electric searchlight projectors. J. H. Johnson. Extract. (J. U. S. Art.), Nov.-Dec., 1916. 760 words. 3 half-tones.—Modern electric searchlight projectors, iii. J .H. Johnson. (Engi.), Oct. 6, 1916. 2390 words. 12 half-tones. Searchlights and other night illuminants applicable for use by the field artillery. E. J. Dawley. (Field Art. J.), July-Sept., 1916. 9330 words.—The Sperry searchlight. Capt. A. Gibson. (J. U. S. Art.), July-Aug., 1916. 1990 words. 1 half-tone. 6 diagrs.

SURVEYING.

Land surveying in Texas. J. M. Howe. (Eng. N.), Oct. 19, 1916. 950 words. 1 diagr.

TRENCHING MACHINES.

Petrol caterpillar tractor and train. (Engi.), Nov. 17, 1912. 940 words, 3 half-tones, 1 diagr.—American trenching machines in the European war. (Eng. N.), Oct. 26, 1916. 730 words.

TROLLHATTAN CANAL.

De opening van het Trollhättan-kanaal. H. A. Van Ijsselsteyn. (De Ing.), Oct. 21, 1916. 2720 words. 2 half-tones, 2 maps, 2 diagrs.

TUNNELS AND TUNNELING.

A 30-mile railway tunnel under the Cascade Mountains. H. M. Chittenden. (Eng. N.), Nov. 6, 1916. 7420 words. 2 half-tones, 2 maps, 2 profiles.

WATER TERMINALS.

Barge canal terminals—their importance and progress of building (Barge canal bull.), Oct., 1916. 2024 words.—Canadian terminal harbors on the Great Lakes. (Ca. E.), Oct. 12, 1916. 552 words. 1 map.—Enormous deep water piers at Halifax. i. ii. (Contracting), Nov., Dec., 1916. 590, 900 words. 3 and 5 half-tones.—Constructing Port Newark terminal, N. J. (Contracting), Nov., 1916. 330 words. 5 half-tones, 1 diagr.

WHARVES.

Municipal docks at Astoria. J. P. Newell. (Eng. N.), Oct. 12, 1916. 2540 words. 2 half-tones, 1 plan, 2 diagrs.—Submarine mine wharf at Fort Armstrong. C. J. Taylor. (Prof. M.), Nov.-Dec., 1916. 2628 words. 5 half-tones.

YADKIN NARROWS DAM.

Famous Yadkin development nearing completion. (Eng. N.), Nov. 16, 1916. 2670 words. 3 half-tones, 1 plan, 2 diagrs.

ZUIDER SEA.

A project for closing up the Zuider Sea by dikes in reinforced concrete. Een ontwerp voor den afsluitdijk der Zuiderzee in gewapend beton door C. Wolterbeck.) De Ingenieur, Sept. 23, 1916. 10130 words. 3 sections, 6 diagrs.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Soc. C. E. P.=American Society of Civil Engineers, N.Y. Proceedings.

Am.Soc.C.E.T.=American Society of Civil Engineers, N. Y. Transactions.

A P.C.=Annales des Ponts et Chaussées, Paris.

A. R.=The Army Review, London.

Assoc'n E. S.=Association of Engineering Societies, St. Louis, Mo. Journal.

B.Eng.C.=Brooklyn Engineers' Club, Brooklyn, N. Y. Proceedings.

Ca.E.=Canadian Engineer, Toronto, Can.

Ca.S.E.=Canadian Society of Civil Engineers (Montreal), Transactions.

Cem. E.=Cement Era, Chicago.

Conn.S.C.E.=Connecticut Society of Civil Engineers, New Haven, Conn. Papers and Transactions.

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K.T.=Kriegstechnische Zeitschrift, Berlin.

Mu.E.=Municipal Engineering, Indianapolis, Ind.

Prof.M.=Professional Memoirs, Corps of Engineers and Engineer Dept. at Large, U. S. A. Washington.

R.Art.=Revue d'Artillerie, Paris.

Rev.G.=Revue du Génie Militaire, Paris.

R.Eng.J.=Royal Engineers Journal, Chatham, England.

R.U.S.I.J.=Royal United Service Institution, London. Journal.

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W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 44, March-April, 1917.)

ARMY WAR COLLEGE.

A combined Army and Navy War College. Wm. W. Harts. (U. S. Nav. I.), Feb., 1917. 2210 words.

AUTOMOBILES, MILITARY.

Armored automobiles. (Sci. Am. S.), Jan. 6, 1917. 2079 words. 1 half-tone.

BANK PAVING.

Five days on the Mississippi. F. C. Wright. (Eng. N.), Dec. 14, 1916. 4870 words. 8 half-tones, 1 map.

BANK PROTECTION (RIVERS).

Develop four types of bank protection in Washington. (Eng. R.), Dec. 2, 1916. 736 words, 4 half-tones. Types of bank protection on the Sacramento River compared. N. A. Bowers. (Eng. R.), Jan. 27, 1917. 3112 words. 7 half-tones, 1 section.

BREAKWATERS.

Large concrete blocks to repair breakwater. (Cem. E.), Jan., 1917. 1020 words. 2 half-tones, 3 diagrams.—Making large concrete blocks for the Panama canal breakwaters. (Eng. N.), Feb. 1, 1917. 1000 words, 3 half-tones, 2 diagrams.

BRIDGES.

The Portland bridge. E. E. Pettee. (Boston Soc. C. E.), Dec., 1916. 6084 words. 18 half-tones, 1 panorma, 9 fold. plates.

CANALS.

The proposed Rhône-Rhine canal. (Engi.), Jan. 19, 1917. 2340 words 1 map.—Contractors' methods on Wellands ship canal work present interesting variations. (Eng. R.), Oct. 21, 1916. 3680 words. 4 half-tones, 1 section, 1 diagram.

CEMENT-CONCRETE.

Concrete-mixer boat for Ohio River locks. A. W. Kreamer and G. M. Dexter. (Eng. N.), Feb. 1, 1917. 3530 words. 6 half-tones, 3 sections.—Large concrete blocks to repair breakwater. (Cem. E.), Jan., 1917. 1020 words. 2 half-tones. 4 diagrs.—Making large concrete blocks for the Panama Canal breakwaters. (Eng. N.), Feb. 1, 1917. 1000 words. 3 half-tones, 2 diagrs.—Temperature changes in mass concrete. C. H. Paul. (Am. Soc. C. E. T.), v. 79, 1915. 11300 words. 2 fold. plates.—Water the chief factor in the making of good concrete. Nath. C. Johnson. (Eng. R.), Dec. 30, 1916. 4752 words. 7 half-tones. Concrete paving for small levee on the Wabash River. G. C. Graeter. (Eng. N.), Jan. 4, 1917. 1632 words. 3 half-tones, 1 diagr.

COAST DEFENSE.

Project for coast defenses. Capt. St. D. Embick. (J .U. S. Art.), Sept. —Oct., 1916. 6600 words.

COAST PROTECTION.

Preservation of sandy beaches in the vincity of New York City. Discus-

sion. B. F. Cresson, jr., and E. J. Dent. (Am. Soc. C. E. P.), Dec., 1916. 4104 words.

COFFER-DAMS.

Cofferdams for Barge canal structures at Troy, N. Y. (Contracting), Dec., 1916. 2450 words. 1 diagr.

COLORADO RIVER.

Favors levees to control lower Colorado River. F. L. Sellow. (Eng. R.), Dec. 2, 1916. 1088 words.

CONCRETE-SEAWATER.

Tests of concrete specimens in seawater, at Boston Navy Yard. R. E. Bakerhus. (Am. Soc. C. E. P.), Dec., 1916. 9774 words.

CONSTRUCTION PLANTS.

Concrete-mixer boat for Ohio River locks. A. W. Kreamer and G. M. Dexter. (Eng. N.), Feb. 1, 1917. 3530 words. 6 half-tones, 3 sections.

COST KEEPING.

Card system records cost of engineering Boston Navy Yard. (Eng. R.), Oct. 21, 1916. 992 words.—The constructive movement for scientific cost accounting. E. N. Hurley. (Elect. Word), Jan. 6, 1917. 1368 words.—Side lights on depreciation problems of utilities 1. H. Barker. (Eng. N.), Dec .21, 1916. 1190 words; ii. (Eng. N.), Dec. 28, 1916. 4550 words.

CRIBWORK.

Repairing timber cribwork. A. E. Eastman. (Ca. E.), Jan. 18, 1917. 1773 words. 1 plan, 2 sections.

DAMS.

Adding 11 ft. to top of Trap-Rock dam at Bridgeport. C. Hirshberg. (Eng. N.), Jan. 11, 1917. 1720 words. 5 half-tones, 1 section, 1 diagr.—Designing an earth dam having a gravel foundation, with results obtained in tests on a model. Discussion. J. B. Hays. (Am. Soc. C. E. P.), Dec., 1916. 1215 words. 4 diagrs.—New multiple-arch dams in the Sierra Nevadas. (Eng. N.), Dec. 21, 1916. 1119 words. 4 half-tones, 1 section.—Plan for raising the heigh of Morena dam. (Eng. N.), Dec. 14, 1916. 1050 words. 3 sections, 1 diagr.—Reservoir capacity increased and construction cost of dam decreased by hydraulic sluicing. (Eng. R.), Dec. 9, 1916. 1536 words. 4 half-tones, 2 sections.

DIKES.

La protection du Mont-Saint-Michel contre l'ensablement. P. Calfas. (Le Génie Civil), Jan. 13, 1917. 6100 words. 3 half-tones, 3 maps, 2 diagrs.—Historic investigation of dikes in North Holland. A. Groothoff. Historisch dijkonderzoek in Noord-Holland door A Groothoff. (De Ing.), Nov. 25, 1916. 3540 words.

DREDGES AND DREDGING.

Hydraulic hopper dredge with unloading machinery. (Eng. N.), Dec. 28, 1916. 400 words. 1 half-tone.

DRIFT BARRIER.

Design of a drift barrier across White River near Auburn, Wash. Discussion. W. J. Roberts. (Am. Soc. C. E. P.), Dec., 1916. 297 words.

ENGINEER TROOPS.

On the Mexican border with the 22d Engineers. i. C. E. Bregenzer. (Eng. R.), Jan. 13, 1917; ii. (Eng. R.), Jan. 20, 1917. 2944 words. 5 half-tones; 2576 words. 5 half-tones.

FLOATING PLANTS.

Concrete-mixer boat for Ohio River locks. A. W. Kreamer and G. M. Dexter. (Eng. N.), Feb. 1, 1917. 3530 words. 6 half-tones, 3 sections.

FLOODS AND FLOOD CONTROL.

Barbed wire helps build river embankments, California. (Eng. R.), Dec. 9, 1916. 440 words. 1 half-tone.—Flood control will make waste land factory sites. (Eng. R.), Dec. 23, 1916. 1575 words.—Floods and flood prevention Discussion. C. McD. Townsend. (Am. Soc. C. E. P.), Jan., 1917. 2394 words. 1 section.—Investigation of flood flow on the Wisconsin River at Merrill, Wis. July 23-24, 1912. C. B. Stewart. (W. S. E. J.), Nov., 1916. 9270 words. 1 half-tone, 2 maps, 12 tables.—Miami flood-prevention plans sustained. (Eng. R.), Dec. 2, 1916. 1024 words.—The Miami Valley flood protection work. i. (Eng. N.), Jan. 4, 1917. 4610 words. 2 maps, 1 section, 7 diagrams; ii. (Eng. N.), Jan. 11, 1917. 3300 words. 1 half-tone, 2 maps, 3 diagrs.; iii. Dam and outlet problems. (Eng. N.), Jan. 25, 1917. 3550 words. 4 half-tones, 3 plans, 10 sections; iv. Study of retarding basin operation. (Eng. N.), Feb. 1, 1917. 2790 words. 3 sections, 2 diagrs.—La protection de Paris contre les inondations. A. Dumas. (Le Génie Civil), Jan. 6, 1917. 6160 words. 2 half-tones, 2 maps, 5 plans.—Wells protected from flood damage by wedges. A. C. Francis. (Eng. R.), Dec. 23, 1916. 352 words. 1 half-tone.

FORTIFICATION.

The future of forts. General Berthaut. (Engi.), Nov. 10, 1916. 2950 words.

GROINS.

Preservation of sandy beaches in the vicinity of New York City. Discussion. B. F. Cresson, jr., and E. J. Dent. (Am. Soc. C. E. P.), Dec., 1916. 4104 words.

HARBORS—France.

Les ports français et la guerre. Les ports secondaires de la méditerranée (suite): Cette et Port-Vendres. A. Pawlowski. (Le Génie Civil), Dec. 30, 1916. 3080 words. 3 half tones, 3 maps.

INLAND NAVIGATION.

Rivers and railroads in the U. S. Wm. W. Harts. (Am. Soc. C. E. T.), v. 79, 1915. With discussion. 28296 words. 4 half-tones.

INSTRUMENTS.

Optical appliances in warfare. C. R. Darling. (Sci. Am. S.), Dec. 30, 1916. 4869 words. 10 diagrs.

INTRENCHMENTS.

Preparing an offensive. (Sci. Am. S.), Jan. 6, 1917. 2223 words. 4 plans, 3 sections.

JETTIES.

Barbed wire helps build river embankment, California. (Eng. R.), Dec. 9, 1916. 440 words, 1 half-tone.

LEVEES.

Better a loan to the Mississippi levees than to the European allies. (Eng. C.), Dec. 13, 1916. 650 words.—Building Mississippi River levees economically and rapidly. (Contracting), Jan., 1917. 1230 words. 1 half-tone.—Concrete paving for small levee on the Wabash River. G. C. Graeter. (Eng. N.), Jan. 4, 1917. 1632 words. 3 half-tones, 1 diagr.—Favors levees to control lower Colorado River. F. L. Sellow. (Eng. R.), Dec. 2, 1916.—Five days on the Mississippi. F. C. Wight. (Eng. N.), Dec. 14, 1916. 4870 words. 8 half-tones, 1 map.—Large levee and drainage system in Indiana. (Eng. N.), Jan. 11, 1917. 1780 words. 5 half-tones, 2 plans and sections.—The St. John levee and drainage district of Missouri. R. M. Strohl. (Am. Soc. C. E. T.), v. 79, 1915. 9376 words. 1 map, 5 fold. plates, 2 diagrs.

MATTRESSES.

Five days on the Mississippi. F. C. Wight. (Eng. N.), Dec. 14, 1916. 4870 words. 8 half-tones, 1 map.—Types of bank protection on the Sacramento River compared. N. A. Bowers. (Eng. R.), Jan. 27, 1917. 3112 words. 7 half-tones, 1 section.

MILITARY ENGINEERING.

On the Mexican border with the 22d Engineers. i. C. E. Bregenzer. (Eng. R.), Jan. 13, 1917; ii. (Eng. R.), Jan. 20, 1917. 2944 words. 5 half-tones; 2576 words. 5 half-tones.

MILITARY POLICY.

The military policy of the United States. F. A. Scott. (Cleveland Eng. Soc.), Journal. Jan., 1917. 5405 words.

MISSISSIPPI RIVER.

Better a loan to the Mississippi levees than to the European allies. (Eng. C.), Dec. 13, 1916. 650 words.—Building Mississippi River levees economically and rapidly. (Contracting), Jan., 1917. 1230 words. 1 half-tone.—Five days on the Mississippi. F. C. Wight. (Eng. N.), Dec. 14, 1916. 4870 words. 8 half-tones, 1 map.

MOTOR TRUCKS.

Motor transport in campaign. Study prepared in War College Division. General Staff. (Field Art. Journal), Oct.—Dec., 1916. 6160 words.—Motor transport in campaign. (J. U. S. Art.), Sept.—Oct., 1916. 4300 words.

PANAMA CANAL.

Facts about the Panama Canal. R. H. Whitehead. (Sci. Am.), Feb. 10, 1917. 1600 words. 3 half-tones.—Large concrete blocks to repair breakwater. (Cem. E.), Jan., 1917. 1020 words. 2 half-tones, 3 diagrs.—Making large concrete blocks for the Panama Canal breakwaters. (Eng. N.), Feb. 1,1917. 1000 words. 3 half-tones, 2 diagrs.

PILE DRIVERS AND PILE DRIVING.

Pile drivers designed and built by three railways. (Eng. N.), Dec. 14, 1916. 610 words. 4 half-tones, 1 diagr.

RESERVOIRS.

Reservoir capacity increased and construction cost of dam decreased by hydraulic sluicing. (Eng. R.), Dec. 9, 1916. 1536 words. 4 half-tones, 2 sections.

REVETMENTS.

Favors levees to control lower Colorado River. F. L. Sellow. (Eng. R.), Dec. 2, 1916.—Types of bank protection on the Sacramento River compared. N. A. Bowers. (Eng. R.), Jan. 27, 1917. 3112 words. 7 half-tones, 1 section.

RHONE-RHINE CANAL.

The proposed Rhône-Rhine canal. (Engi.), Jan. 19, 1917. 2340 words. 1 map.

RIVER TERMINALS.

A municipal river terminal system for St. Louis. S. W. Bowen. (Engineer Club, St. Louis.) Nov.—Dec., 1916. 936 words.

RUN-OFF AND RAINFALL.

Computing run-off from rainfall and other physical data. Ad. F. Meyer. (Am. Soc. C. E. T.), v. 79, 1915. 48492 words. 39 diagrs.

SEARCHLIGHTS.

Searchlights. Extracts from thesis prepared at U. S. Coast Art. School. C. W. Baird and Edw. P. Noyes. (U. S. Art. J.), Jan.—Feb., 1917. 9460 words. 1 half-tone, 2 diagrs.

SILT AND SILTING.

La protection du Mont-Saint Michel contre l'ensablement. P. Calfas. (Le Génie Civil), Jan. 13, 1917. 61600 words. 3 half-tones, 3 maps, 2 diagrs.

SURVEYING.

The stereoscopic method of surveying, and a first trial of its application to a railway survey in China. G. A. G. Mueller. (Am. Soc. C. E. T.), v. 79, 1915. 10297 words 7 half-tones, 14 diagrs.

TRANSPORTATION.

Rivers and railroads in the United States. Wm. W. Harts. (Am. Soc. C. E. T.), v. 79, 1915. With discussion. 28296 words. 4 half-tones.

WELLAND SHIP CANAL.

Contractors' methods on Welland ship canal work present interesting variations (Eng. R.), Oct. 21, 1916. 3680 words. 4 half-tones, 1 section, 1 diagr.

WHARVES.

New municipal dock at St. Louis. (Eng. N.), Dec. 28, 1916. 1050 words. 1 half-tone, 3 diagrs.—Plans, specifications and unit prices for the dock under construction at North Market Street. C. E. Smith. (Engineer Club, St. Louis), Nov.—Dec., 1916. 11310 words. 1 fold. plate.

WHITE RIVER.

Design of a drift barrier across White River near Auburn, Wash. Discussion. W. J. Roberts. (Am. Soc. C. E. P.), Dec.. 1916. 297 words.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Soc. C. E. P.=American Society of Civil Engineers, N.Y. Proceedings.

Am.Soc.C.E.T.=American Society of Civil Engineers, N. Y. Transactions.

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Assoc'n E. S.=Association of Engineering Societies, St. Louis, Mo. Journal.

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Ca.E.=Canadian Engineer, Toronto, Can.

Ca.S.E.=Canadian Society of Civil Engineers (Montreal), Transactions.

Cem. E.=Cement Era, Chicago.

Conn.S.C.E.=Connecticut Society of Civil Engineers, New Haven, Conn. Papers and Transactions.

Con.=The Contractor, Chicago.

De Ing.=De Ingenieur Hague, Holland.

Engi.=The Engineer, London.

Eng.=Engineering, London.

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Eng.M.=Engineering Magazine, N.Y.

Eng.N.=Engineering News, N. Y.

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Eng.C.P.=Engineers' Club of Phila. Proceedings.

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Inst.C.E.=Institution of Civil Engineers, London. Minutes of Proceedings.

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Int.R.=Internationale Revue über die gesamten Armeen und Flotten, Dresden.

J.R.Art.=Journal of the Royal Artillery, Woolwich, England.

J.U.S.Art.=Journal, U. S. Artillery, Fort Monroe, Va.

K.T.=Kriegstechnische Zeitschrift, Berlin.

Mu.E.=Municipal Engineering, Indianapolis, Ind.

Prof.M.=Professional Memoirs, Corps of Engineers and Engineer Dept. at Large, U. S. A. Washington.

R.Art.=Revue d'Artillerie, Paris.

Rev.G.=Revue du Génie Militaire, Paris.

R.Eng.J.=Royal Engineers Journal, Chatham, England.

R.U.S.I.J.=Royal United Service Institution, London. Journal.

Sci.Am.=Scientific American, N. Y.

Sci.Am.S.=Scientific American Supplement, N. Y.

Soc.Eng.=Society of Engineers, London. Transactions.

Tech.M.=La Technique Moderne, Paris.

U.S.Nav.I.=U. S. Naval Institute, Annapolis, Md. Proceedings.

W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 45, May-June, 1917.)

BANK PROTECTION (Rivers).

Dams of boulder-filled wire baskets built in California. (Eng. N.), April 12, 1917. 1010 words. 1 illus.

BARGES.

Effects of collision on concrete pontoons. (Concrete), Jan., 1917. 400 words.—The first concrete boats. (Concrete), Jan., 1917. 350 words.

BIG SUNFLOWER RIVER, MISS.

Box cofferdams on the Ouachita and Big Sunflower rivers. T. C. Thomas. (Prof. M.), Jan.-Feb., 1917. 8,000 words. 6 half-tones, 3 tables, 2 fold. pl., 2 plans.

BORINGS.

Submarine rock excavation; borings for contractors' estimates. (Prof. M.), Jan.-Feb., 1917. 1100 words.

BREAKWATERS.

Breakwater and jetty construction in the New London, Conn., district. G. E. Verrill. (Prof. M.), Jan.-Feb., 1917. 7500 words. 12 half-tones, 2 fold. pl., 2 plans.

BRIDGES.

Arcaded cantilever cased in concrete feature a million-dollar bridge. (Eng. N.), March 29, 1917. 2410 words. 5 illus., 3 diagrs.—New Columbia River Interstate bridge remarkable for its length. F. M. Cortelyou. (Eng. N.), March 29, 1917. 680 words. 2 illus.

CAISSONS.

Bridge caissons sunk in river where tide varies 33 feet, creating 15-mile-an-hour current. C. H. Hollingsworth. (Eng. N.), April 12, 1917. 4240 words. 3 illus., 2 diagrs.

CANALS—FRANCE.

Accident et restauration de la Digue de Charmes. Alimenation du canal de la Marne à la Saône. (Le Génie Civil), Feb. 3, 1917. 3080 words. 2 diagrs., 1 half-tone.

CANALS—GREAT BRITAIN.

The value of British canals. Editorial. (Eng.), March 2, 1917. 1701 words.

CANALS—NETHERLANDS.

Le Canal Wilhelmine et ses écluses. A. Goupil. (A. P. C.), Sept.-Oct., 1916. 972 words. 7 diagrs.

CANALS—SWEDEN.

Le nouveau canal de Trollhaettan à Göteborg, Suède. (Le Génie Civil), Feb. 17, 1917. 3290 words. 3 half-tones, 4 diagrs.

CAPE FEAR RIVER, N. C.

Subaqueous concrete work on the Cape Fear River, N. C. Capt. C. S. Ridley. (Prof. M.), Jan.-Feb., 1917. 5000 words. 5 half-tones, 2 fold. pl.

CEMENT-CONCRETE.

Arcaded cantilever cased in concrete feature a million-dollar bridge. (Eng. N.), March 29, 1917. 2410 words. 5 illus., 6 diagrs.—Effects of

collision on concrete pontoons. (Concrete), Jan., 1917. 400 words.—Final report of the Special Committee on Concrete and reinforced concrete. Discussion. A. H. Rhett. (Am. Soc. C. E. P.), Feb., 1917. 1116 words.—The first concrete boats. (Concrete), Jan., 1917. 350 words.—Levee paving with concrete. T. M. McCarroll. (Prof. M.), Jan.-Feb., 1917. 5500 words. 11 half-tones, 1 fold. pl., 2 diagrs.—Lining a flood channel with concrete. A. S. Fry. (Contractor), March 16, 1917. 1540 words. 5 half-tones.—Special forms for jacketing wood piles with concrete. (Eng. N.), Feb. 15, 1917. 400 words. 2 illus.

COFFER-DAMS.

Box cofferdams on the Ouachita and Big Sunflower river. T. C. Thomas. (Prof. M.), Jan.-Feb., 1917. 8000 words. 6 half-tones, 3 tables, 2 fold. pl., 2 plans.—Sheet pile cutoff wall allows work close to cofferdam. C. F. Nimmo. (Eng. N.), March 22, 1917. 300 words. 2 illus.—Unusual cofferdam for 1,000 ft. pier, New York City. C. W. Standiford. (Am. Soc. C. E. P.), Feb., 1917. 15000 words. Half-tones, diagrs.

CONCRETE-SEAWATER.

Effect on reinforced steel of using salt water in concrete. J. L. Harrison. (Concrete), March, 1917. 2400 words. 1 half-tone.—Tests of concrete specimens in sea water at Boston Navy Yard. Discussion. T. K. Thomson and others. (Am. Soc. C. E. P.), Feb., 1917. 4104 words.

CORROSION.

Whitewash as a rust preventive. M. Meigs. (Prof. M.), No. 44, 1917. 1100 words. 1 half-tone.

COST-KEEPING.

Cost accounting for the contractor and its relation to his organization. L. H. Allen. (Ca. E.), March 29, 1917. 1932 words.—Practical costs. iii. Distributing the burden. Earl S. Clark. (Eng. N.), March, 1917. 1400 words. 4 diagrs.

DAMS.

Adobe dam in Philippines dewatered and leaks repaired. (Eng. R.), March 31, 1917. 528 words. 1 half-tone.—Build high earth dam by alternate ridge-and-wet-trench method. (Eng. R.), March 17, 1917. 1128 words. 1 half-tone, 2 diagrs.—Concrete spillway defects caused by construction negligence. (Eng. N.), April 5, 1917. 1200 words. 8 half-tones, 3 outline cuts.—Construction of the Stony River dam. F. W. Scheidenhelm. (Am. Soc. C. E. P.), Feb., 1917. 44460 words. Half-tones, diagrs.—Coreless hydraulic-fill dam built of lava. J. W. Swaren. (Eng. N.), March 29, 1917. 900 words. 1 illus., 1 diagr.—Fixed dams to replace movable dams on the Upper Ohio. (Eng. N.), March 22, 1917. 1410 words.—Slide gates and needle valves in the Elephant Butte dam. F. Teichman. (Eng. N.), Feb. 22, 1917. 3200 words. 2 diagrs.

DIAMOND DRILLING.

Diamond drilling at Muscle Shoals, Tenn. River. W. S. Winn. Prof. M.), no. 44, 1917. 9000 words. 4 half-tones, 4 outline cuts, 1 fold. pl.

DIKES.

Accident et restauration de la Digue de Charmes. Alimenattion du

Canal de la Marne à la Saône. (Le Génie Civil), Feb. 3, 1917. 3080 words. 1 half-tone, 4 diagrs.—Notice sur l'accident de la Digue de Charmes, Oct., 1909. M. Frontard. (A. P. C.), Sept.-Oct., 1914. 30708 words, 1 half-tone, 20 sections, 17 diagrs., 7 tables.

DREDGES AND DREDGING.

Clamshell dredge with 195-ft. boom. (Eng. N.), March 1, 1917. 1500 words. 2 half-tones.—Notes on the U. S. dredge Barnard. (Prof. M.), no. 44, 1917. 1600 words. 4 half-tones.—The passes of the Mississippi River. Their description. . . . Lt. Col. Edw. H. Schulz. (Prof. M.), no. 44, 1917. 14000 words. 7 fold. pl., 1 table.—Rock removal table on suction pipe of a hydraulic dredge. O. Quinlivan. (Prof. M.), no. 43, 1917. 1200 words. 2 half-tones, 1 plan.

ELEPHANT BUTTE DAM. See DAMS.

ENGINEER OFFICERS' RESERVE CORPS.

Army Engineer Reserve Corps filling. (Eng. N.), March 1, 1917. 1300 words.

ENGINEER TROOPS.

Civilian engineers instruct rookies at Citizens' training camp. J. W. Swaren. (Eng. N.), April 5, 1917. 2200 words. 8 half-tones, 5 outline cuts. —Consolidation of trenches, localities and craters after assault and capture. (Prof. M.), no. 44, 1917. 9000 words. 22 outline cuts.—War Dept. forming Engineer enlisted reserve corps. (Eng. N.), Feb. 22, 1917. 420 words.

EXPLOSIVES.

Projectiles containing explosives, by Com'dt. A. R. Trans. by C. E. Munroe. (U. S. Nav. I.), April, 1917. 6550 words.

FLOODS AND FLOOD CONTROL.

Dry reservoir for flood control on the Oder River in Germany. K. C. Grant. (Eng. N.), Feb. 22, 1917. 1300 words. 1 half-tone.—Flood control in the Miami Valley. A. E. Morgan. (Boston Soc. C. Eng.), Feb., 1917. 8800 words. 3 tables, 2 diagrs.—Lining a flood channel with concrete. A. S. Fry. (Contractor), March 16, 1917. 1540 words. 5 half-tones.—The Miami Valley flood-protection work. v: New features in the specifications. (Eng. N.), Feb. 15, 1917. 6000 words.

FORTIFICATION, FIELD.

Consolidation of trenches, localities and craters after assault and capture. (Prof. M.), no. 44, 1917. 9000 words. 22 outline cuts.—Field fortification. Authentic sources. (Infantry Journal), April, 1917. 4200 words. 57 illus., 10 diagrs.

FOUNDATIONS.

Diamond drilling at Muscle Shoals, Tenn. River. W. S. Winn. (Prof. M.), no. 44, 1917. 9000 words. 4 half-tones, 1 fold. pl., 4 outline cuts.

GROINS.

Experiment with groins at Santa Monica Beach successful. W. Woodward. (Eng. R.), March 31, 1917. 1000 words. 1 half-tone.

HANDLING MATERIALS.

Time savers in handling material. W. P. Kennedy. (Eng. M.), March, 1917. 3400 words. 18 half-tones.

HARBORS—AUSTRALIA.

The port of Melbourne. Construction of a new railway pier. A. C. Mackenzie. (Commonwealth Engineer), Feb. 1, 1917. 2028 words. 2 half-tones, 2 diagrs.

HARBORS—FRANCE.

Les ports français et la guerre. Dieppe et Le Tréport. A. Pawlowski. (Le Génie Civil), 24 Mars, 1917. 5750 words. 4 half-tones, 2 maps, 6 tables. —The same. Rouen et Le Havre. (Le Génie Civil), Feb. 10, 1917. 10490 words. 6 half-tones, 10 diagrs.

HARBORS—GREAT LAKES.

Permanent superstructures on harbor piers, Milwaukee, Wis., district. J. A. B. Tompkins. (Prof. M.), no. 43, 1917. 5500 words. 2 half-tones, 5 plans, 2 diagrs.

HYDRAULICS.

Filling and emptying the third lock at St. Marys Falls canal, Mich. L. C. Sabin. (Prof. M.), no. 44, 1917. 4500 words. 4 half-tones, 1 fold. pl., 7 diagrs., 2 tables.

INLAND NAVIGATION.

L'Importance des ports sur les voies de navigation intérieure. Jacquinot. (Le Génie Civil), 31 Mars, 1917. 3340 words, 3 plans.

INTRENCHMENTS.

Consolidation of trenches, localities and craters after assault and capture. (Prof. M.), no. 44, 1917. 9000 words. 22 outline cuts.—What is new in intrenching. (Military Historian and Economist), Jan., 1917. 337 words; April, 1917.

JETTIES.

Breakwater and jetty construction in the New London, Conn., district. G. E. Verrill. (Prof. M.), no. 43, 1917. 2500 words. 12 half-tones, 2 fold. pl., 2 plans.—Columbia River jetty rapidly nearing completion. W. P. Hardesty. (Eng. R.), March 31, 1917. 1560 words. 1 half-tone, 4 illus.—The passes of the Mississippi River. Lt. Col. Edw. H. Schulz. (Prof. M.), no. 44, 1917. 14000 words. 7 fold. pl., 1 table.

LEVEES.

Levee paving with concrete. T. M. McCarroll. (Prof. M.), no. 43, 1917. 5500 words. 11 half-tones, 1 fold. pl., 2 diagrs., 1 table.—The methods of levee location. W. E. Knobloch. (Prof. M.), no. 44, 1917. 5000 words. 3 half-tones, 3 outline cuts.

LOCKS AND LOCK GATES.

Completing the world's busiest waterway. The 4th lock at Sault Ste. Marie. T. H. Wade. (Sci. Am.), Feb. 24, 1917. 1632 words. 4 half-tones. —Filling and emptying the third lock at St. Marys Falls canal, Mich. L. C. Sabin. (Prof. M.), no. 44, 1917. 4500 words. 4 half-tones, 1 fold. pl., 7 diagrs., 2 tables.—Ship canal from Swedish lake to ocean. (Eng. N.), Feb. 22, 1917. 840 words. 3 half-tones.—Subaqueous concrete work on the Cape Fear River, N. C. Capt. C. S. Ridley. (Prof. M.), no. 43, 1917. 5000 words. 5 half-tones, 2 fold. pl.

LONG ISLAND SOUND.

Breakwater and jetty construction in the New London, Conn., district. G. E. Verrill. (Prof. M.), no. 43, 1917. 7500 words. 12 half-tones, 2 fold. pl., 2 plans.

MASONRY CONSTRUCTION.

Historic failures of masonry structures. H. R. Thayer. (Eng. S. W. P.), Feb., 1917. 16510 words. 4 half-tones, 5 diagrs.

MATTRESSES.

Brush mattresses floated from sloping platform. (Eng. R.), March 17, 1917. 432 words. 2 half-tones.

MISSISSIPPI RIVER.

Methods of levee location. W. E. Knobloch. (Prof. M.), no. 44, 1917. 5000 words. 3 half-tones, 3 outline cuts.—The passes of the Mississippi River. Lt. Col. Edw. H. Schulz. (Prof. M.), no. 44, 1917. 14000 words. 7 fold. pl., 1 table.

MOTOR TRUCKS.

Lessons from the army motor trucks on the Mexican border. C. F. Harrington. (Eng. N.), Feb. 15, 1917. 500 words.—Motor transportation in the Marine Corps. Capt. F. E. Evans, U. S. M. C., ret. (Marine Corps Gazette), March, 1917. 5280 words. 6 half-tones.—Testing trucks for the U. S. Army. (Am. Machinist), March 29, 1917. 60 words. 6 half-tones.—Time savers in handling material. W. P. Kennedy. (Eng. M.), March, 1917. 3400 words. 18 half-tones.

MUSCLE SHOALS, TENNESSEE RIVER.

Diamond drilling at Muscle Shoals, Tennessee River. W. S. Winn. (Prof. M.), no. 44, 1917. 9000 words. 4 half-tones, 1 fold. pl., 4 outline cuts.

OCEAN TERMINALS.

Halifax ocean terminals. A. C. Brown. (Ca. E.), April 12, 1917. 4358 words. 2 illus., 1 diagr.

ODER RIVER.

Dry reservoir for flood control on the Oder River in Germany. K. C. Grant. (Eng. N.), Feb. 22, 1917. 1300 words. 1 half-tone.

OHIO RIVER.

Fixed dams to replace movable dams on the Upper Ohio. (Eng. N.), March 22, 1917. 1410 words.

OUACHITA RIVER, LA.

Box cofferdams on the Ouachita and Big Sunflower rivers. T. C. Thomas. (Prof. M.), no. 43, 1917. 8000 words. 6 half-tones, 2 fold. pl., 2 plans, 3 tables.

PIERS.

Baltimore and Ohio opens new coal pier at Baltimore. (Eng. R.), March 17, 1917. 648 words. 1 half-tone.—Permanent superstructures on harbor piers, Milwaukee, Wis., district. J. A. B. Tompkins. (Prof. M.), no. 43, 1917. 5500 words. 2 half-tones, 5 plans, 3 diagrs.—The port of Melbourne construction of a new railway pier. A. C. Mackenzie. (Commonwealth Engineer), Feb. 1, 1917. 2029 words. 2 half-tones, 2 diagrs.

PILES AND PILING.

Bottom driven concrete piles on government job. C. S. Howell. (Eng. N.), Dec. 28, 1916. 750 words, 1 section.—Driving concrete sheetpiles true to line and position. E. A. Bailey. (Eng. N.), Feb. 22, 1917. 360 words. 2 half-tones, 3 sections.—Sheet pile cutoff wall allows work close to cofferdam. C. F. Nimmo. (Eng. N.), March 22, 1917. 800 words. 2 illus.—Special forms for jacketing wood piles with concrete. (Eng. N.), Feb. 15, 1917. 400 words. 2 illus.

RAINFALL AND RUN-OFF.

Run-off computations for 70000-acre storm-water drainage, St. Louis. (Eng. N.), March 22, 1917. 1560 words. 1 diagr., 2 tables.

RESERVOIRS.

Dry reservoir for flood control on the Oder River in Germany. K. C. Grant. (Eng. N.), Feb. 22, 1917. 1300 words. 1 half-tone.—Du rôle des réservoirs dans la régularisation des cours d'eau. Wilhelm. (A. P. C.), Nov.-Dec., 1916. 6290 words.

RIVERS—REGULATION.

Du rôle des réservoirs dans la régularisation des cours d'eau. (A. P C.), Nov.-Dec., 1916. 6290 words.—Ottawa and St. Lawrence rivers regulation. C. R. Coutlee. (Ca. E.), March 22, 1917. 1800 words.

RIVER TERMINALS.

L'importance des ports sur les voies de navigation intérieure. Jacquinot (Le Génie Civil), 31 Mars, 1917. 3340 words, 3 plans.

ROCK EXCAVATION.

Powerful drill-car effective in uneven, spongy rock. J. B. Bassell. (Eng. N.). April 12, 1917. 2120 words. 1 illus., 1 diagr.

ST MARYS FALLS CANAL, MICH. See also LOCKS AND LOCK GATES.

SALVAGE.

Raising the sunken dismantled steamship City of Panama. (Prof. M.), no. 44, 1917. 2000 words. 2 half-tones, section, elevation, plan.

SEARCHLIGHTS.

First military use of searchlights. (Prof. M.), no. 43, 1917. 500 words.

SHIP-CANALS. See also TROLLHAETTAN CANAL.

STONY RIVER DAM. See DAMS.

SUBAQUEOUS CONCRETE.

Subaqueous concrete work on the Cape Fear River, N. C. Capt. C. S. Ridley. (Prof. M.), no. 43, 1917. 5000 words. 5 half-tones, 2 fold. pl.

TRANSPORTATION, MILITARY. See also MOTOR TRUCKS.

TROLLHAETTAN CANAL. See also LOCKS AND LOCK GATES.

WHARVES.

Baltimore and Ohio opens new coal pier at Baltimore. (Eng. R.), March 17, 1917. 648 words. 1 half-tone.

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J.U.S.Art.=Journal, U. S. Artillery, Fort Monroe, Va.

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Sci.Am.=Scientific American, N. Y.

Sci.Am.S.=Scientific American Supplement, N. Y.

Soc.Eng.=Society of Engineers, London. Transactions.

Tech.M.=La Technique Moderne, Paris.

U.S.Nav.I.=U. S. Naval Institute, Annapolis, Md. Proceedings.

W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 46, July-August, 1917)

BANK PROTECTION (Rivers).

Current deflectors protect banks on Southwestern rivers. (Eng. N.), April 26, 1916. 280 words, 3 half-tones.—Improvement of Mississippi River from Winona to La Crosse in accordance with the 6-ft. channel project adopted by Congress, March 2, 1907. W. A. Thompson and H. M. Anderly. (Prof. M.), no. 45. 2766 words. 4 half-tones, 1 table. 5 fold. plates.

BRIDGES.

Stone bridges in French battle area rapidly rebuilt. (Eng. N.), May 10, 1917. 800 words. 2 diagrs.

CANALS—CANADA.

Economic and strategic aspects of enlargement of Welland Canal and of construction of Georgian Bay ship canal. R. W. Leonard. (Ca. S. E.), Jan.-June, 1916. 5350 words.

CANALS—FRANCE.

The Marseilles-Rhône canal. (Sci. Am. S.), May 12, 1917. 1536 words. 1 diagr., 1 map.

CEMENT-CONCRETE. See also Subaqueous Concrete.

Concrete consistency measured by simple field test. H. A. Thomas. (Eng. N.), May 3, 1917. 2270 words. 1 diagr.—Concrete poles now made here by centrifugal process. (Eng. N.), May 24, 1917. 940 words. 1 half-tone.—Final report of the Special Committee on Concrete and Reinforced Concrete. Discussion. W. F. Scott. (Am. Soc. C. E. P.), March, 1917. 1458 words. 1 diagr.; Discussion. C. Gayler. (Am. Soc. C. E. P.), April, 1917. 800 words.

CLEVELAND BREAKWATER.

Durability of timber in Cleveland breakwater. Maj. J. P. S. Bond. (Prof. M.), no. 504 words. 1 half-tone.

COAST DEFENSE.

Car-mounted gun reduces coast defense to engineering problem. (Eng. N.), April 26, 1916. 1350 words. 5 half-tones.

COFFER-DAMS.

Coffer-dam framed with slotted piles used successfully on uneven rock bottom. K. D. Maclean. (Eng. N.), May 24, 1917. 960 words. 1 half-tone, 1 diagr.—Coffer-dam for new lock at St. Marys Falls canal, Sault Ste. Marie, Mich. Its design, construction and cost. W. J. Graves. (Prof. M.), no. 45, 5524 words. 4 half-tones, 9 diagrs., 1 table, 1 fold. pl.—Unusual coffer-dam for 1000-ft. pier, New York City. Discussion. (Am. Soc. C. E. P.), April, 1917. 5300 words. 8 half-tones, 4 plans, diagrs., etc.

CONCRETE—SEAWATER.

Tests of concrete specimens in sea water, at Boston Navy Yard. Discussion. M. W. Brown. (Am. Soc. C. E. P.), April, 1917. 500 words; Discussion. A. H. Rhett. (Am. Soc. C. E. P.), March, 1917. 999 words.

DAMS.

Barrage à arches multiples en béton armé sur la Sélune (Manche). A. Pawlowski. (Le Génie Civil), May 12, 1917. 2310 words. 5 half-tones, 7 line-cuts.—How Stanley Lake dam was built and the story of the slips. J. E.

Hayes. (Eng. N.), May 31, 1917. 3470 words. 2 half-tones, 3 diagrs., 1 plan.—Ohio flood-control dam has duplex outlets. (Eng. N.), May 24, 1917. 860 words, 10 diagrs.—One engineers' opinion as to why the Standley Lake dam sloughed. A. L. Fellows. (Eng. N.), May 31, 1917. 760 words. 2 half-tones.—The reconstruction of the Stony River dam. Discussion. J. W. Ledoux and others. (Am. Soc. C. E. P.), April, 1917. 6000 words.

DAMS, MOVABLE.

Will combine Mohawk and sector types in Genesee River. (Eng. N.), May 24, 1917. 430 words. 3 diagrs.

DEMOLITIONS.

Triton electroplating plant at Washington Barracks. Lieut. R. W. Crawford. (Prof. M.), no. 45. 5378 words. 1 half-tone, 1 line-cut, 1 table, 1 fold. plate.

EXPLOSIVES.

La fabrication des principales matières explosives et l'utilisation des produits résiduaires. J. Meunier. (Le Génie Civil), April 28, 1917. 2550 words; May 6, 1917. 3440 words.

FLOODS AND FLOOD CONTROL.

Ohio flood-control dam has duplex outlets. (Eng. N.), May 24, 1917. 860 words. 10 diagrs.—Progress report on Special Committee on Floods and Flood Prevention. Discussion. M. Knowles. (Am. S. C. E. P.), March, 1917. 279 words.—River levees and flood control. Abstract of paper on Goulburn levees. G. Higgins. (Commonwealth Engineer), May 1, 1917. 2444 words. —River straightening again active at Cleveland. (Eng. N.), May 3, 1917. 780 words. 1 map.

FORTIFICATION, FIELD. See also Intrenchments.

Field fortification. (Infantry Journal), March, 1917. 4080 words. 10 diagrs.; April, 1917. 928 words. 64 figs.; May, 1917. 870 words. 6 half-tones, 7 line-cuts.

GOULBURN LEVEES. See Floods and Flood Control.

HARBORS—FRANCE.

Les ports français et la guerre: Caen-Quistreham et les hauts furneaux de Caen. A. Pawlowski. (Le Génie Civil), April 28, 1917. 5670 words. 4 half-tones, 5 plans.

HARBORS—NETHERLANDS.

De haven van Breskens. H. Van Oordt. (De Ing.), May 5, 1917. 3100 words. 3 diagrs.

HARBORS—SOUTH AMERICA.

Chilean city to spend 6500000 for harbor construction. F. McCoy. (Eng. N.), April 26, 1917. 500 words. 2 half-tones.

HARBORS—UNITED STATES.

Wilmington to enlarge its Delaware River port. (Eng. N.), May 24, 1917. 450 words. 1 half-tone.

INTRENCHMENTS.

Military Engineering. What Germany has learned from Russia about trench-

es and cover. A. K. Dawson. (Sci. Am.), May 26, 1917. 1792 words. 7 half-tones. 3 diagrs. *Illustrations*: Section of barbed wire entanglements that formed a barrier about the city of Kiaochow.—Typical Russian barbed wire entanglements, machine gun emplacements, trenches and underground quarters.—German officers' quarters concealed in the woods, in Northern France.—Russian field fortifications in Galicia, captured by the Germans.

LEVEES.

River levees and flood control. Abstract of paper on Goulburn levees. C. Higgins. (Commonwealth Engineer), May 1, 1917. 2444 words.

LOCKS AND LOCK GATES.

Construction of north guide wall of Troy lock without enclosing with coffer-dam. J. J. McCabe. (Prof. M.), no. 45. 2426 words. 1 half-tone, 5 sections and plans.—Improving the Ohio River below Pittsburgh. Widening the Louisville and Portland canal at Louisville, Ky. Maj. J. C. Oakes. (Prof. M.), no. 45. 8010 words. 8 half-tones, 1 table, 1 fold. pl.—Nyholm system of lock operation. G. Bendixen. (Prof. M.), no. 45. 2224 words. Plan and section.

LOUISVILLE AND PORTLAND CANAL. See under LOCKS AND LOCK GATES.

MEXICO—PUNITIVE EXPEDITION, U. S., 1916.

Road work in Mexico with the punitive expedition. Capt. J. A. O'Connor. Comments. Maj. Lytle Brown. (Prof. M,), no. 45. 7630 words. 11 half-tones.

MILITARY ENGINEERING. See Intrenchments.

MILITARY ROADS. See MEXICO.

MISSISSIPPI RIVER.

Improvement of Mississippi River from Winona to La Crosse in accordance with the 6-ft. channel project adopted by Congress, March 2, 1907. W. A. Thompson and H. M. Anderly. (Prof. M.), no. 45. 2766 words. 4 half-tones, 1 table. 5 fold. plates.

MOTOR TRUCKS.

Motor truck mobilization for the Mexican operations of U. S. Army. (Eng. C.), May 16, 1917. 1200 words.

MOVABLE CRESTS. See SLUICE GATES.

NYHOLM SYSTEM. See LOCKS AND LOCK GATES.

OHIO RIVER.

Improving the Ohio River. See LOCKS AND LOCK GATES.

PIERS. See Coffer-dams.

PLATTSBURG TRAINING CAMP.

Engineer exhibit at Plattsburg, 1916. (Prof. M.), no. 45. 864 words.

PONTONS.

Pontoon for transporting stock across the Zambesi River, Rhodesia. (Eng.), March 23, 1917. 400 words. 4 half-tones.

RIVERS—REGULATION. See also BANK PROTECTION (Rivers).

River straightening again active at Cleveland. (Eng. N.), May 3, 1917. 780 words. 1 map.

ST. MARYS FALLS CANAL. See COFFER-DAMS.

SALVAGE.

Engineering contractors recover stranded submarine ''H-3''. (Eng. N.), May 24, 1917. 1380 words. 4 half-tones.

SAND DUNES.

Sand devastation. P. Collins. (Sci. Am. S.), May 5, 1917. 1880 words. 12 half-tones.

SAND FENCES.

Sand-drift barriers protect road across desert. (Eng. N.), May 3, 1917. 1039 words. 2 half-tones, 1 diagr.

SEARCHLIGHTS.

Notes on the employment of searchlights and luminous projectiles in land warfare. Capt. Di Tondo. Trans. Comdr. R. H. Keate. (R. U. S. I. J.), Nov., 1916. 4220 words.

SLUICE GATES. See also LOCKS AND LOCK GATES.

Adjustable sluice-gates with automatic control. Nyholm system. G. Bendixen. (Prof. M.), no. 45. 588 words. 1 half-tone, 1 line-cut.

SPUR DIKES. See BANK PROTECTION (RIVERS)

SUBAQUEOUS CONCRETE.

Construction of north guide wall of Troy Lock without enclosing with coffer-dam. J. J. McCabe. (Prof. M.), no. 45. 2426 words. 1 half-tone, 5 sections and plans.

''TANKS''. See TRACTORS, MILITARY.

TIMBER PRESERVATION.

Durability of timber in Cleveland breakwater. Maj. P. S. Bond. (Prof. M.), no. 45. 504 words. 1 half-tone.—Timber decay and its growing importance to the engineer and architect. C. J. Humphrey. (W. S. E. J.), Feb., 1917. 11550 words. 8 half-tones.

TRACTORS, MILITARY.

Automobili corazzati e armati da battaglia i ''Tanks'' inglesi. (Rivista di Artiglieria e Genio, Roma.) v. 1, 1917. 1940 words. 2 fig. (half-tone).

TRANSPORTATION.

When ship freight by motor truck and when by rail? C. C. Williams. (Eng. N.), May 10, 1917. 1360 words.

TRENCHING MACHINES.

Trench digging for French army. (Eng. C.), May 16, 1917. 170 words. 2 half-tones.

TROY LOCK. See LOCKS AND LOCK GATES.

WIRE ENTANGLEMENTS. See INTRENCHMENTS.

The articles on Coast Defense; Field fortification; Intrenchments; Motor Trucks; Searchlights; Tractors; Transportation and Trenching machines will be of special interest to the new army in connection with its prospective work at the front.—W. R. L.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Soc. C. E. P.=American Society of Civil Engineers, N.Y. Proceedings.

Am.Soc.C.E.T.=American Society of Civil Engineers, N. Y. Transactions.

A P.C.=Annales des Ponts et Chaussées, Paris.

A. R.=The Army Review, London.

Assoc'n E. S.=Association of Engineering Societies, St. Louis, Mo. Journal.

B.Eng.C.=Brooklyn Engineers' Club, Brooklyn, N. Y. Proceedings.

Ca.E.=Canadian Engineer, Toronto, Can.

Ca.S.E.=Canadian Society of Civil Engineers (Montreal), Transactions.

Cem. E.=Cement Era, Chicago.

Conn.S.C.E.=Connecticut Society of Civil Engineers, New Haven, Conn. Papers and Transactions.

Con.=The Contractor, Chicago.

De Ing.=De Ingenieur Hague, Holland.

Engi.=The Engineer, London.

Eng.=Engineering, London.

Eng.C.=Engineering and Contracting, Chicago.

Eng. M.=Engineering Magazine, N. Y.

Eng. N.=Engineering News, N. Y.

Eng. R.=Engineering Record, N. Y.

Eng.C.P.=Engineers' Club of Phila. Proceedings.

Eng.S.P.=Engineers' Society of Pennsylvania. Harrisburg. Journal.

Eng.S.W.P.=Engineers' Society of Western Penn'a. Pittsburg, Pa. Proceedings.

Inst.C.E.=Institution of Civil Engineers, London. Minutes of Proceedings.

Inst.Eng.Sh.=Institute of Engineers and Shipbuilders in Scotland, Glasgow. Transactions.

Int.R.=Internationale Revue über die gesamten Armeen und Flotten, Dresden.

J.R.Art.=Journal of the Royal Artillery, Woolwich, England.

J.U.S.Art.=Journal, U. S. Artillery, Fort Monroe, Va.

K.T.=Kriegstechnische Zeitschrift, Berlin.

Mu.E.=Municipal Engineering, Indianapolis, Ind.

Prof.M.=Professional Memoirs, Corps of Engineers and Engineer Dept. at Large, U. S. A. Washington.

R.Art.=Revue d'Artillerie, Paris.

Rev.G.=Revue du Génie Militaire, Paris.

R.Eng.J.=Royal Engineers Journal, Chatham, England.

R.U.S.I.J.=Royal United Service Institution, London. Journal.

Sci.Am.=Scientific American, N. Y.

Sci.Am.S.=Scientific American Supplement, N. Y.

Soc.Eng.=Society of Engineers, London. Transactions.

Tech.M.=La Technique Moderne, Paris.

U.S.Nav.I.=U. S. Naval Institute, Annapolis, Md. Proceedings.

W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 47, Sept.-Oct., 1917.)

AERIAL WARFARE.

Military aeronautics. Major Wm. Mitchell. (Eng. C. P.), July, 1917. 7752 words. 1 half-tone.—Hulpinrichting voor het suel en juist richten van een anti-luchtvaartkanon. J. K. E. Triebart. (De Ing.), May 19, 1917. 13000 words. 1 half-tone, 4 diagrs.—Anti-aircraft weapons. Maj. E. J. Wallace. (J. U. S. Art.), May-June, 1917. 8220 words. 18 half-tones, plans, sections, etc.

AMMUNITION.

Royal visit to munition factories. (Eng.), May 25, 1917. 2745 words. 2 half-tones, 1 fold. plate.

ANTI-AIRCRAFT GUNS. See AERIAL WARFARE.

ARMORED CARS.

Mobile armament for defense. A. M. Coyle. (Am. Soc. Mech. Eng., Journal), Aug., 1917. 1400 words, 3 half-tones, 2 diagrams, 1 section.

Fig. 1, British armored car with 12-lb. naval gun mounted in center—Fig. 2, First modern armored car built in America.—Fig. 3, Section of coast defense gun with spherical mount.—Fig. 4, French car carrying howitzer.—Fig. 5, Diagrams showing methods of stabilizing.—Fig. 6, Gun with special recoil device mounted on R. R. car, and circular track for traversing the car.

ARMORED TURRETS.

Resistenza delle opere cora-zzate. (Rivista di Artiglieria e Genio, Genu, Febb. e Marzo) 1917. 115 words.

See International Military Digest, Aug., 1917. p. 464.

ARMY CANTONMENTS.

What a camp for 40,000 men looks like. (Eng. N.), July 26, 1917. 300 words. 1 plan.

BAYONET.

Bayonet fighting and physical training. Maj. P. Hobbs. (Infantry Journal), Aug., 1917. 3780 words.

BIBLIOGRAPHY.

Military books for engineers. (Eng. C. P.), July, 1917. 2304 words.

BREAKWATERS.

Breakwaters protect Chicago's municipal pier. (Eng. N.), July 26, 1917. 590 words. 10 cross-sections, etc.

BULKHEAD WALLS.

Building the Jacksonville bulkhead. (Contracting), June, 1917. 2130 words, 6 half-tones, 1 diagr.—Concrete bulkhead wall replaces old timber structure. (Eng. N.), June 21,1917. 1000 words, 1 plan, 1 section.—Lake shore protection at Chicago being built of concrete. M. D. Blumberg. (Eng. N.), June 14, 1917. 1870 words, 2 half-tones, 2 plans.

CANALS—GT. BRITAIN.

The canal problem, Editorial. (Engi.), March 9, 1917. 1690 words.—Forth and Clyde ship canal. (Eng.), July 13, 1917. 700 words, 2 maps.—Le trafic des canaux en Angleterre. (Le Genie Civil), May 26, 1917. 860 words.

CANALS—U. S.

The Cape Cod Canal. Wm. P. Parsons. (Am. Soc. C. E. P.), Aug., 1917. 17126 words, 1 map, 8 cross-sections, 8 diagrams.—N. Y. State and her Barge canal. L. H. Hart. (Cleveland Eng. Soc.), May, 1917. 8228 words, 12 half-tones, 1 map, profile, cross-section and plan of lock.

CEMENT—CONCRETE.

Concrete lock paving done first in rapid construction of Ohio River dam 35. G. W. McAlpin. (Eng. N.), June 14, 1917. 2720 words, 3 half-tones, 2 diagrams, 1 plan.

Lake shore protection at Chicago, built of concrete. M. D. Blumberg. (Eng. N.), June 14, 1917. 1870 words, 2 half-tones, 2 plans.—The Raymond concrete pile. (Eng.), May 25, 1917. 540 words, 2 half-tones, 1 section.—Strength of concrete affected by water. (Concrete), July, 1917. 1560 words, 1 diagram.

COAST PROTECTION.

Construction on an exposed shore. Wooden groins built with shore derrick. (Contracting), Aug., 1917. 530 words, 3 half-tones.

COST-KEEPING.

The basis of manufacturing costs. H. L. Gantt. (Eng. M.), June, 1917. 1176 words.—Cost-keeping system for small bridge and culvert jobs. (Eng. C.), June 27, 1917. 296 words.

DAMS.

Settlement observed on two earth dams in Porto Rico. J. M. Giles. (Eng. N.), June 21, 1917. 890 words. 2 sections, 2 tables.

DAMS—OHIO RIVER.

Concrete lock paving done first in rapid construction of Ohio River dam 35. G. W. McAlpin. (Eng. N.), June 14, 1917. 2720 words, 3 half-tones, 2 diagrams, 1 plan.

DREDGES AND DREDGING.

The three 15-cubic yard dipper-dredges Gamboa, Paraiso, and Cascades, as supplied and used on the Panama Canal. R. W. Berdeau, J. (Am. Soc. C. E. P.) Aug., 1917. 689 words, 2 fold-plates, 1 diagram.

ENGINEER TROOPS.

Engineering instruction by the First Corps Cadets, and the formation of a new engineer regiment. J. F. Osborn. (Bost Soc. C. Eng.), June, 1917. 2232 words, French officer discusses Engineer's part in war. (Eng. N.), Aug. 16, 1917. 558 words. Portrait.—Captain Capart, of General Petain's staff, tells of selection of consulting engineers as members of the General Staff. Organization and duties of Engineer troops. F. B. Downing. (Bost. Soc. C. Eng.), June, 1917. 2472 words.—Task of U. S. Engineer regiments in France. (Eng. N.), Aug. 9, 1917. 790 words.

FLOODS AND FLOOD CONTROL.

The protection of Paris against floods. (Engi.), July 6, 1917. 3300 words. 1 diagram. 1 cross-section, 1 plan, 2 maps.

FORTIFICATION.

Re-introducing the concrete-and-steel fortification. (Sci. Am.), July 7, 1917. 1180 words, 2 half-tones.

FORTIFICATION, FIELD.

Field fortification. Authentic sources. iv. Defensive organization of a sector. (Infantry Journal), Aug., 1917. 1014 words. 4 plans, 21 diagrams. —Field fortification. Organization of intrenched zones. (Infantry Journal), July, 1917. 6912 words, 16 outline fig.

GRENADES.

Granate a mano e da fucile. (Rivista di Artiglieria e Genio), Gen., febb. e Marzo, 1917. 65 words.—Grenades used by the Austrians. See International Military Digest, Aug., 1917. p. 465.

GROINS.

Construction on an exposed shore. Wooden groins built with shore derrick. (Contracting), Aug., 1917. 530 words, 3 half-tones.

HARBORS—CANADA.

Halifax's new $30000000 docks. J. F. Stephens, jr. (Sci. Am.), Aug. 11, 1917. 720 words. 5 half-tones.—Progress in Toronto harbor developments. (Ca. E.), Aug. 16, 1917. 3200 words, 6 half-tones, 1 plan, 1 section.

HARBORS—FRANCE.

Les ports francais et la guerre. Cherbourg et Brest. A. Pawlowski. (Le G. C.), July 14, 1917. 3330 words. 3 half-tones, 3 plans.—Les ports francais et la guerre. Honfleur et Saint-Malo. A. Pawlowski. (Le Genie Civil), June 2, 1917. 4550 words, 3 half-tones, 2 plans, 3 tables.—Les ports francais et la guerre. Mouvement des marchandises les principaux ports. A Dumas. (Le Genie Civile), May 26, 1917. 3560 words, 2 tables.

HARBORS—SOUTH AMERICA.

Harbour improvements at Valparaiso. (Engi.), June 8, 1917. 590 words, 8 half-tones.

HARBORS—U. S.

Lake port improvements many and varied. (Engi.), June 14, 1917. 2340 words.

INLAND NAVIGATION.

French inland waterways. (Eng.), June 29, 1917. 2650 words.

INSTRUMENTS.

Instrument repair work on the Canal Zone. F. A. Stanley. (Am. Machinist), July 5, 1917. 1100 words, 5 half-tones.

INTRENCHMENTS.

Newest wrinkles in trench-building. (Literary Digest), July 21, 1917. 1800 words, illus. A popular article. Digested in International Military Digest, Aug., 1917. p. 452.

LANDING OPERATIONS.

Landing operations. Degouy (R. U. S. I. J.), May, 1917. 1370 words.

LANDSCAPE SKETCHING.

Panoramic sketching. Maj. E. H. Lovell. (Marine Corps Gazette), June, 1917. 2156 words, 9 fig., 3 diagrs.; 1 fold. plate.

LOCKS AND LOCK GATES.

New York State and her Barge canal. L. H. Hart. (Cleveland Eng. Soc.), May, 1917. 8228 words. 12 half tones. Map, profiles, cross-section, etc. —Concrete lock paving done first in rapid construction of Ohio River dam 35. G. W. McAlpin. (Eng. N.), June 14, 1917. 2720 words, 3 half tones, 2 diagr., 1 plan.

MACHINE GUNS.

Characteristics of machine guns. Capt. J. J. Dooley. (Marine Corps Gazette), June, 1917. 2992 words. 4 half-tones.—The Lewis machine gun (Am. Machinist), July 5, 1917. 2940 words, 2 half-tones, 1 diagr.—Machine guns and wire. Capt. H. Carre. (Infantry Journal), July, 1917. 9298 words.—The Vickers machine gun model of 1915. (Am. Machinist), Aug. 23, 1917. 6670 words, 5 half-tones, 5 diagr.

MAPS, MILITARY.

Aeronautcal charts. O. B. Whitaker. (Geographical Review), July, 1917. 1800 words. 2 illus. See Int. Mil. Digest, Aug., 1917. p. 466.—European war maps. (Geographical Review), July, 1917. 1800 words. See Int. Mil. Digest, Aug., 1917. p. 466.

MATERIALS OF CONSTRUCTION.

''Testing Materials'' meeting greatest in its 20 years existence. (Eng. N.), July 5, 1917. 3680 words.

MILITARY BRIDGES.

Brakesman bridge. Lt. Col. G. F. Wilkinson. (R. Eng. J.), Aug., 1917. 1128 words. 1 fold. plate.—Bridge has span of 180 feet can be erected in 15 minutes. Built on side of obstacles to be crossed, then drawn into position by the team-horses hitched to front tool cart. Designed for infantry in file, but can be adapted to carry infantry in fours.

MILITARY ENGINEERING.

Engineering in the great European war. F. W. Skinner. (Sci. Am. S.), July 28, 1917. 3014 words.

MILITARY ROADS.

Mill road construction in France. (Eng. C.), Aug. 1, 1917. 640 words. —Mill road construction at Mt. Gretna, Pa. (Eng. C.), 850 words, 4 half-tones. Aug. 1, 1917.

MILITARY TRAINING CAMPS.

What a camp for 40000 men looks like. (Eng. N.), July 26, 1917. 300 words, 1 plan.

MILITARY SANITATION.

Military Sanitation. W. P. Chamberlain. (Bost. Soc. Civ. Eng.), June, 1917. 1872 words.

MILITARY TOPOGRAPHY.

Night operations. Capt. Waldon. (Infantry Journal), July, 1917. 3888 words. 4 diagr., 1 map.

MOBILE ORDNANCE.

Mobile armament for defense. A. M. Coyle. (Am. Soc. Mech. Eng., Journal), Aug., 1917. 1400 words. 3 half-tones, 2 diagrs., 1 section.

Fig. 1. British armored car with 12-lb. naval gun mounted in center.

Fig. 2. First modern armored car built in America. Fig. 3. Sec. of coast defense gun with spherical mount. Fig. 4. French car carrying howitzer. Fig. 5. Diagrams showing methods of stabilizing. Fig. 6. Gun with special recoil device mounted on railroad car, and circular track for traversing the car.

MOTOR TRUCKS.

The Army tractor that drives like a horse. (Sci. Am.), May 19, 1917. 480 words, 1 half-tone.—Lesson of the great war in motor truck design. W. C. Thomas. (Commercial Vehicle), July 15, 1917. 1500 words; July 22, 1917. 2600 words. Article digested in Int. Mil. Digest, Aug., 1917. p. 467.—Mechanical aids in loading and unloading trucks. J. S. Harwhite. (Sci. Am.), May 19, 1917. 1730 words, 8 half-tones.—Military influence on motor trucks design. H. D. Church. (Cleveland Eng. Soc.), May, 1917. 12278 words.—Military motor truck design. H. D. Church. (Sci. Am. S.), July 7, 1917. 4140 words.—Motor traction in modern war. V. W. Page. (Sci. Am.), May 19, 1917. 1976 words, 5 half-tones.—Motor tractors and trailers. J. Brinker. (Sci. Am.), May 19, 1917. 2160 words. 6 half-tones.

OHIO RIVER. See LOCKS AND LOCK GATES.

PANAMA CANAL. See also INSTRUMENTS.

PANORAMIC SIGHTS.

The panoramic sight. W. L. Olmstead. (American Machinist), Aug. 2, 1917. 2300 words. 6 half-tones, 1 diagram. Fig. 1. Panoramic sight, model 1917. Fig. 2. Diagr. showing process of sighting on an aiming point. Fig. 3. Panoramic sight mounted on sight bar and sight shank. Fig. 4. Front view of panoramic sight mounted. Fig. 5. Side view of panoramic sight mounted on sight bar and sight shank. Fig. 6. Unit assemblies of sight, showing position of parts and official relations. Aug. 16, 1917. 2250 words, 7 half-tones, Elevations and cross-sections. Fig. 7. Rotating-head group. Fig. 8. Elevations and cross-sections showing details of 1917 panoramic gun sight. Fig. 9. Hood details. Fig. 10. Worm details and their relation to the hood. Fig. 11. Prominent components of the body group. Fig. 12. Elbow group and assembled eye-piece. Fig. 13. Rotating-head prism holder.

PHOTOGRAPHY, MILITARY.

Militay airplane photography. A. Brock, jr. (Aviation), May 15, 1917. 3948 words. illus.

Digested in International Military Digest, Aug., 1917, p. 470-471. 882 words.—Photography from air-craft. Col. Dion Williams. (Marine Corps Gazette), June, 1917. 4188 words, 12 half-tones.

PHYSICAL TRAINING.

Bayonet fighting and physical training. Maj. P. Hobbs. (Infantry Journal), Aug., 1917. 3780 words.

PILES AND PILING.

Building the Jacksonville bulkhead. (Contracting), June, 1917. 2138 words. 6 half-tones, 1 diagr.

RIFLE.

The military rifle. (Sci. Am. S.), July 7, 1917. 1150 words, 3 half-tones.

SAPPING AND MINING.

With the soldiers who fight underground. (Sci. Am.), June 9, 1917. 430 words. Illus.

SEARCHLIGHTS.

Practical limitations in the projection of light. J. A. Orange. (General Electric Review), July, 1917. 4116 words. 1 half-tone.

SEAWATER—CONCRETE.

Effect of sea water on some of the concrete structures in the Philippine Islands. J. L. Harrison. (Eng. C.), June 27, 1917. 1968 words. 4 half-tones. 1 diagr.

SHORE PROTECTION.

Lake shore protection at Chicago built of concrete. M. D. Blumberg. (Eng. N.), June 14, 1917. 1870 words, 2 plans, 2 half-tones.

SIGHTS. See also PANORAMIC SIGHTS.

Sighting telescopes for fire-arms. E. Coustet. (Sci. Am.), July 21, 1917. 2223 words. 8 fig.

SUBMARINES.

The submarine. Bibliography of the literature. (Am. Soc. Naval Eng.), Aug.,, 1917. 603 words.—The submarine problem. vi. Detecting U-boats. (Sci. Am.), July 7, 1917. 3508 words. 3 half-tones.—Submarines in periodical literature from 1911 to 1917. H. R. Hosmer (Franklin Institute), Aug. 1917. 20000 words. A digest of articles published in domestic and foreign journals.

"TRENCH-FOOT."

One job of the staff captain. (Sphere), May 26, 1917. 1200 words. Article digested in International Military Digest, Aug., 1917, p. 475.

TRENCHING MACHINES.

Digging trenches by machinery. (Sci. Am.), Aug. 11, 1917. 580 words. 2 half-tones.—Trenching machine work. W. W. Brush. (Ca. E.), June 28, 1917. 985 words. 1 half-tone, 1 section.

UNITED STATES ARMY.

The United States Marine Corps. A military body qualified for duty with either army or navy. (Sci. Am.), July 28, 1917. 1392 words. 7 half-tones.

WHARVES. See also BULKHEAD WALLS.

WIRE ENTANGLEMENTS.

Machine guns and wire. Capt. H. Carré. (Infantry Journal), July, 1917. 9298 words.

Articles of Engineering Interest.

Compiled with a view to including articles of civil and military engineering subjects of special interest to the readers of PROFESSIONAL MEMOIRS, Corps of Engineers and Engineer Department at Large. By Henry E. Haferkorn, Librarian, Engineer School.

The following abbreviations are used, viz:

Am. Soc. C. E. P.=American Society of Civil Engineers, N.Y. Proceedings.

Am.Soc.C.E.T.=American Society of Civil Engineers, N. Y. Transactions.

A P.C.=Annales des Ponts et Chaussées, Paris.

A. R.=The Army Review, London.

Assoc'n E. S.=Association of Engineering Societies, St. Louis, Mo. Journal.

B.Eng.C.=Brooklyn Engineers' Club, Brooklyn, N. Y. Proceedings.

Ca.E.=Canadian Engineer, Toronto, Can.

Ca.S.E.=Canadian Society of Civil Engineers (Montreal), Transactions.

Cem. E.=Cement Era, Chicago.

Conn.S.C.E.=Connecticut Society of Civil Engineers, New Haven, Conn. Papers and Transactions.

Con.=The Contractor, Chicago.

De Ing.=De Ingenieur Hague, Holland.

Engi.=The Engineer, London.

Eng.=Engineering, London.

Eng.C.=Engineering and Contracting, Chicago.

Eng. M.=Engineering Magazine, N. Y.

Eng. N.=Engineering News, N. Y.

Eng. R.=Engineering Record, N. Y.

Eng.C.P.=Engineers' Club of Phila. Proceedings.

Eng.S.P.=Engineers' Society of Pennsylvania. Harrisburg. Journal.

Eng.S.W.P.=Engineers' Society of Western Penn'a. Pittsburg, Pa. Proceedings.

Inst.C.E.=Institution of Civil Engineers, London. Minutes of Proceedings.

Inst.Eng.Sh.=Institute of Engineers and Shipbuilders in Scotland, Glasgow. Transactions.

Int.R.=Internationale Revue über die gesamten Armeen und Flotten, Dresden.

J.R.Art.=Journal of the Royal Artillery, Woolwich, England.

J.U.S.Art.=Journal, U. S. Artillery, Fort Monroe, Va.

K.T.=Kriegstechnische Zeitschrift, Berlin.

Mu.E.=Municipal Engineering, Indianapolis, Ind.

Prof.M.=Professional Memoirs, Corps of Engineers and Engineer Dept. at Large, U. S. A. Washington.

R.Art.=Revue d'Artillerie, Paris.

Rev.G.=Revue du Génie Militaire, Paris.

R.Eng.J.=Royal Engineers Journal, Chatham, England.

R.U.S.I.J.=Royal United Service Institution, London. Journal.

Sci.Am.=Scientific American, N. Y.

Sci.Am.S.=Scientific American Supplement, N. Y.

Soc.Eng.=Society of Engineers, London. Transactions.

Tech.M.=La Technique Moderne, Paris.

U.S.Nav.I.=U. S. Naval Institute, Annapolis, Md. Proceedings.

W.S.E.J.=Western Society of Engineers, Chicago, Ill. Journal.

(Prepared for PROFESSIONAL MEMOIRS, v. 9, No. 48, Nov.-Dec., 1917.)

ARMY CANTONMENTS.

Building army city in wilderness was the problem at Camp Pike. (Eng. N.), Sept. 20, 1917. 1660 words. 2 half-tones.—Building stepped to fit hillsides at Camp Gordon, Atlanta. (Eng. N.), Sept. 13, 1917. 1540 words. 5 half-tones, 1 plan—500 teams save day in deep mud at Camp Lee. (Eng. N.), Sept. 13, 1917. 1940 words. 2 half-tones—Logging road carry lumber to each brigade at Columbia camp. H. D. Hammond. (Eng. N.), Sept. 13, 1917. 2390 words. 3 half-tones, 1 plan.

BANK PROTECTION (RIVERS).

River erosion and their prevention. S. J. Pollitzer. (Commonwealth Engineer), Aug. 1, 1917. 2520 words. 10 outline figs.

BAYONET.

New principal of bayonet fighting. Andre-Gaucher. (Marine Corps Gazette), Sept. 1917. 5200 words, 3 plates.

BOMB-PROOF SHELTERS.

German shelters on the Somme. Trans. by Col. W. R. Livermore. (Prof. M.), July-Aug., 1917. 1900 words, 5 plans.

CAMOUFLAGE.

Entrenchments and camouflage. (Prof. M.), Sept.-Oct., 1917. 25200 words. 3 half-tones, 41 diagrams.

CEMENT-CONCRETE.

Precautionary measure for concreting in freezing weather. J. A. Stalfort. (Cem. E.), Oct., 1917. 2180 words.

CEMENT-GUN.

Repointing sea wall at Governors Island, N. Y., with cement-gun. H. N. Babcock. (Prof. M.), July-Aug., 1917. 2500 words. 6 figures.

CONCRETE PILING.

Concrete wharf supports in San Francisco Harbor. T. S. Willliams. (Prof. M.), July-Aug., 1917. 3000 words.

CONCRETE-SEAWATER.

Reinforced concrete in sea water fails from corroded steel. R. J. Wig and L. R. Ferguson. (Eng. N.), Oct. 11, 1917. 5340 words. 4 half-tones.—What is the trouble with concrete in sea water R. J. Wig and L. R. Ferguson. (Eng. N.), Sept. 20, 1917. 2540 words. 2 half-tones.

DEMOLITION.

Destruction of barbed-wire entanglements. (Field Art. Journal), July-Sept., 1917. 610 words. 2 half-tones.

DREDGES AND DREDGING.

Sand and gravel digger, designed and built for Ohio River. A. W. Kreamer. (Eng. N.), Sept. 13, 1917. 2660 words. 1 half-tone, 6 plans.

DRY-DOCKS.

Sidehaul railway dry dock at West Memphis, Ark. (Prof. M.), July-Aug., 1917. 1740 words. 3 half-tones, 2 plates.

MILITARY RAILROADS.

The war work of railways. (Eng.), Sept. 7, 1917. 1845 words.

MILITARY ROADS.

Road maintenance in the war zone of France as observed by a U. S. Highway engineer driving an American ambulance. Wm. J. Weir (Eng. N.), Sept. 13, 1917. 5350 words.

MOTOR TRUCKS.

Coal gas for motor vehicles. (Engi.), Sept. 14, 1917. 1400 words. 1 half-tone.—First details of the miraculous track work performed in saving Verdun. W. F. Bradley. (Commercial Vehicle), Aug. 1, 1917. 3500 words. Sketch map, illus. See Int. Mil. Digest, Sept., 1917. p. 527.—Lessons of the great war in motor truck design. W. O. Thomas. (Commercial Vehicle), Aug. 1, 1917. 2300 words. Digested in Int. Mil. Digest, Sept., 1917. p. 528.—Motor trucks haul heavy, bulky loads up mountain side. F. Reed. (Eng. N.), Oct. 11, 1917. 660 words. 2 half-tones.—Table shows complete average operating costs of trucks. R. W. Horne. (Eng. N.), Sept. 20, 1917. 750 words.

OBSERVATION BALLOONS.

Observation balloons and artillery fire. (Sci. Am. S.), Sept. 8, 1917. 558 words.

ORDNANCE.

Shells of the fighting nations. (Sci. Am. S.), Sept. 29, 1917. 2500 words. 2 figs.

PANORAMIC SIGHTS.

The panoramic sight. W. L. Olmstead. Machine operations on headpiece. (Am. Machinist), Aug. 30, 1917. 2050 words. 36 figs., Sept. 27, 1917. 2470 words. 4 half-tones, 6 cross-sections, 6 diagrs.

REDOUBTS.

German shelter on the Somme. Trans. by Col. W. R. Livermore. (Prof. M), July-Aug., 1917. 1900 words. 5 plans.

RHINE RIVER.

Extracts from ''Des travaux de fleuve du Rhin.'' A. J. Defontaine. Tr. by Col. C. McD. Townsend. (Prof. M.), Sept.-Oct., 1917. 10500 words.

RIVER ENGINEERING. See also RHINE RIVER.

ROADS.

Practical roadwork in the United Kingdom. E. G. Wilson. (Soc. Eng.), Sept., 1917. 6520 words.

SEARCHLIGHTS.

Device for giving an image of searchlight arc in full size outside of the searchlight drum. Capt. A. Gibson. (J. U. S. Art), Nov.-Dec., 1916. 600 words. Illus. Digested in Int. Mil. Digest, Sept., 1917. p. 531.—Photometric test of flood lighting projectors. S. L. E. Rose. (General Electric Review), Sept., 1917. 768 words, half-tones, 5 tables, 4 diagrs.

SEA WALLS.

Repainting sea walls at Governors Island, N. Y., with cement gun. H. N. Babcock. (Prof. M.), July-Aug., 1917. 2500 words. 6 figs.

SUBMARINES.

Dry docking Submarines in the Gatun locks. F. A. Stanley. (Am. Machinist), Sept. 20, 1917. 450 words. 6 half-tones.

TRACTORS, MILITARY.

Le tracteur automobile militaire. (La Nature, Paris), v. 43, pt. 2, No. 2192, 1 Oct., 1915, p. 209-214. 7 half-tones.

Fig. 1. Groupe de canons de 120 longs attelés à des tracteurs Latil. Fig. 2. Tracteur Renault et ses remorques. Fig. 3. Tracteur Renault sur forte pente. Fig.4. Sortie d'une mare. Fig. 5. Tracteur Latil passant un gué. Fig. 6. Tracteur Schneider & Cie. passant un fossé au moyen de ponceaux. Fig. 7. Tracteur dit "Chenille" à adhérence totale.

Fig. 7 has "mobile" rails.

TRACTORS, MILITARY.

Trains automobiles avec roues à rails mobiles. L. Bayette. (La Nature, Paris), v. 43, pt. 2, No. 2183. 31 juillet, 1915, p. 80. 1 half-tone.

Illus.: Train automobile à rails mobiles utilisé en Australie.
Constructed by Wilfly Co., London.

The evolution of the chain-track tractor. (The Engineer, London). v. 124, nos. 3215-3219. Aug. 10, 17, 24, 31; Sept. 7, 1917.

No. 3215. Aug. 10, 1917, p. 111-112. 1 outline fig. 3400 words.

Fig. 1. A Boydell traction engine.

No. 3216. Aug. 17, 1917, p. 135-136. 9 outline figs. 2770 words.

Fig. 2. The Andrew Dunlop wheel of 1861. Fig. 3. The same of 1874. Fig. 4. Section of rail of Dunlop wheel. Fig. 5-13. Sections. Guillaume Fender proposals, 1882.

No. 3217. Aug. 24, 1917, p. 156-158. 9 outline figs. 3550 words.

Fig. 14. Elevation and plan of the Batter tractor, 1888. Fig. 15. Sketch showing arrangement of Woolbridge tractor, 1882. Fig. 16. Sketch showing arrangement of Applegarth tractor, 1886. Fig. 17. Arrangement of the Page vehicle, 1884. Fig. 18. The Edwards tractor, 1890. Figs. 19, 20. Cross-section and side view of Edwards' tractor, 1890. Fig. 21. The original Diplock traction engine, 1893. Fig. 22. Sketch showing Gwinnett's proposal, 1895.

No. 3218. Aug. 31, 1917, p. 181-184. 4 half-tones, 14 outline figs. 4120 words.

Fig. 23. Sketch showing Walker's proposal, 1895. Fig. 24. Section of Walker wheel-rim and chain-track. Fig. 25. Sketch showing Angell's proposal, 1896. Fig. 26. Sketch showing Beamont's proposal, 1900. Fig. 27. The Justice-Johnson proposals, 1896. Fig. 28. The Justice-Johnson chain-track. Fig. 29. Diplock's pedrail wheel, 1899. Fig. 30. The pedrail climbing an incline. Fig. 31. Sections of pedrail feet. Fig. 32. Diplock's original pedrail, 1901. Fig. 33. Pedrail, no. 2, 1903. Fig. 34. Pedrail, no. 3, 1905. Fig. 35. Pedrail, no. 4, 1908. Fig. 36. Sketch showing Beamond's proposal, 1905. Fig. 37. Section of Beamond's chain-track. Fig. 38. Beamond's track applied to pneumatic tire. Fig. 39. The Lombard chain-track and anti-friction roller chain, 1901. Fig. 40. The Simms ploughing tractor, 1902.

No. 3219. Sept. 7, 1917. 13 half-tones, 8 outline figs. 4500 words.

Fig. 41. The original Roberts' chain-track tractor, 1904. Fig. 42. The Roberts' caterpillar tractor, 1904. Fig. 43. Roberts' chain-track, 1904. Figs. 45, 46. Roberts' tractor on trial, 1905. Fig. 47. Plan and sections, Roberts' chain-track, 1906. Fig. 48. Rochet-Schneider car fitted with Roberts' chain-track, 1907. Fig. 49. Roberts' chain-track fitted to a 40-H. P. Hornsby tractor, 1907. Fig. 50. The Phoenix Company's log-hauling tractor, 1906-1907. Fig. 51. Driving arrangements of Phoenix Co's tractor. Fig. 52. The centiped chain-track. Fig. 53. The Lombard log-hauling tractor, 1907. Fig. 54. Improved Lombard arrangement, 1913. Fig. 55. Caterpillar, or paddle-wheel traction engine, 1909. Fig. 56. Tractor hauling a gun on uneven ground. Fig. 57. Tractor hauling a gun up hill. Fig. 58. Tractor climbing a heavy slope. Fig. 59. View of tractor, showing chain-tracks.

Figs. 5-13 shows a South American invention, G. Fender, of Buenos Aires, patented by John Clayton Mewburn, London, 1882. G. F. Page's (Baltimore, Md.) patent is shown in fig. 17. Other American inventors among the above are R. S. Angell, fig. 25—James Allen Justice, and Peter Johnson, both of Macey, Ark., figs. 27-28—Alvin O. Lombard, Waterville, Me., figs 39, 53, and The Phoenix Manufacturing Co., Eau Claire, Wis.—Rochet-Schneider is a French, and the balance of machines shown in illustrations are of British origin.

No. 3220. Sept. 14, 1917, p. 221-224. 2800 words. 2 half-tones (figs. 60,65), 6 outline figs.

Fig. 60. Mercedes car fitted with chain-track by Hornsby's 1908. Figs. 61-63. Sections, showing Roberts' and James' chain-track, 1908. Fig. 64. Roberts' and James' track driving mechanism, 1909. Fig. 65. The Hornsby chain-track tractor of 1909. Fig. 66. The Diplock original chain-track, 1910. Fig. 67. Details of the Diplock chain-track, 1910.

The evolution of the chain-track tractor. Letter to Editor by L. Sterne, London. (The Engineer, London). v. 124, no. 3218, Aug. 31, 1917, p. 184. 5 sections. 420 words.

Refers to patents no. 599 and 2620 taken out by the writer in 1870. No. 599 consisted in forming tires of segmented blocks of india-rubber, united to metal plates. No. 2620 had shoes fitted to the rubber to meet the requirements of the War Office.

What's inside of a "tank?" (Popular Science Monthly), May, 1917. 1048 words. Illus.—When the gasoline cavalry charges. With the French tanks during a typical battle. (Sci. Am.), Aug. 4, 1917. 1600 words. 5 half-tones. See Int. Mil. Digest, Sept., 1917. p. 501.

TRENCHING MACHINES.

Machines for trench digging. (Field Artillery Journal), July-Sept., 1917. 870 words. 2 half-tones.

TRENCH WARFARE.

Entrenchments and camouflage. (Prof. M.), Sept.-Oct., 1917. 25200 words. 3 half-tones, 41 diagrs.—German method of trench warfare. (Prof. M.), Sept.-Oct., 1917. 3000 words, 1 fold. plate.—German raid on British trench. (Infantry Journal), Sept., 1917. 2100 words.

VERDUN, OFFENSIVE, Feb. 21-29, 1916.

German method of trench warfare. (Prof. M.), Sept.-Oct., 1917. 3000 words. 1 fold. plate.

WATER SUPPLY.

Measures for disinfecting water pipes. A. Stucchi. (Revista del Circulo Militar, Buenos Aires), March, 1917. 1000 words. Article digested in Int. Mil. Digest, Aug., 1917. p. 485.

WATER TERMINALS.

Syracuse canal terminal built over old salt works. (Eng. N.), Sept. 20, 1917. 1040 words. 1 half-tone, 3 plans.

WHARVES.

Concrete wharf supports in San Francisco harbor. T. S. Williams. (Prof. M.), July-Aug., 1917. 3000 words.

WIRE ENTANGLEMENTS.

Destruction of barbed-wire entanglements. (Field Art. Journal), July-Sept., 1917. 610 words. 2 half-tones.

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Vol. IX. NOVEMBER-DECEMBER, 1917. No. 48.

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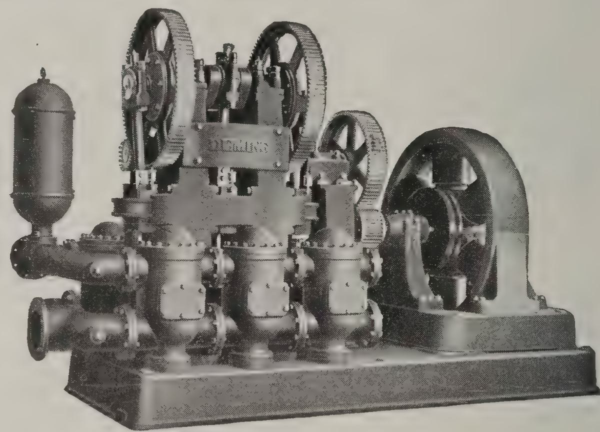

Fig. 51

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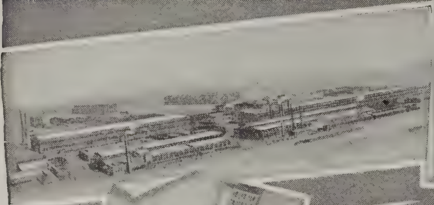

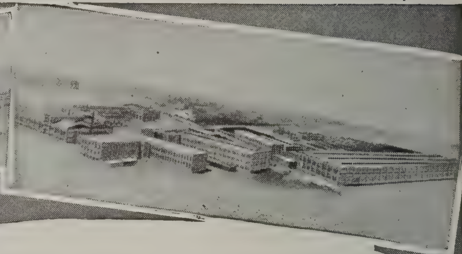

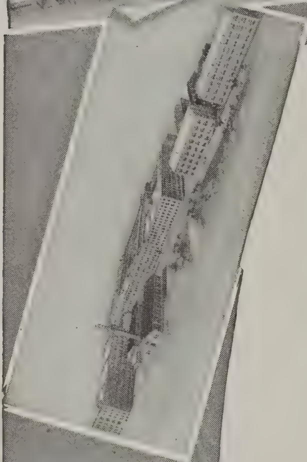

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